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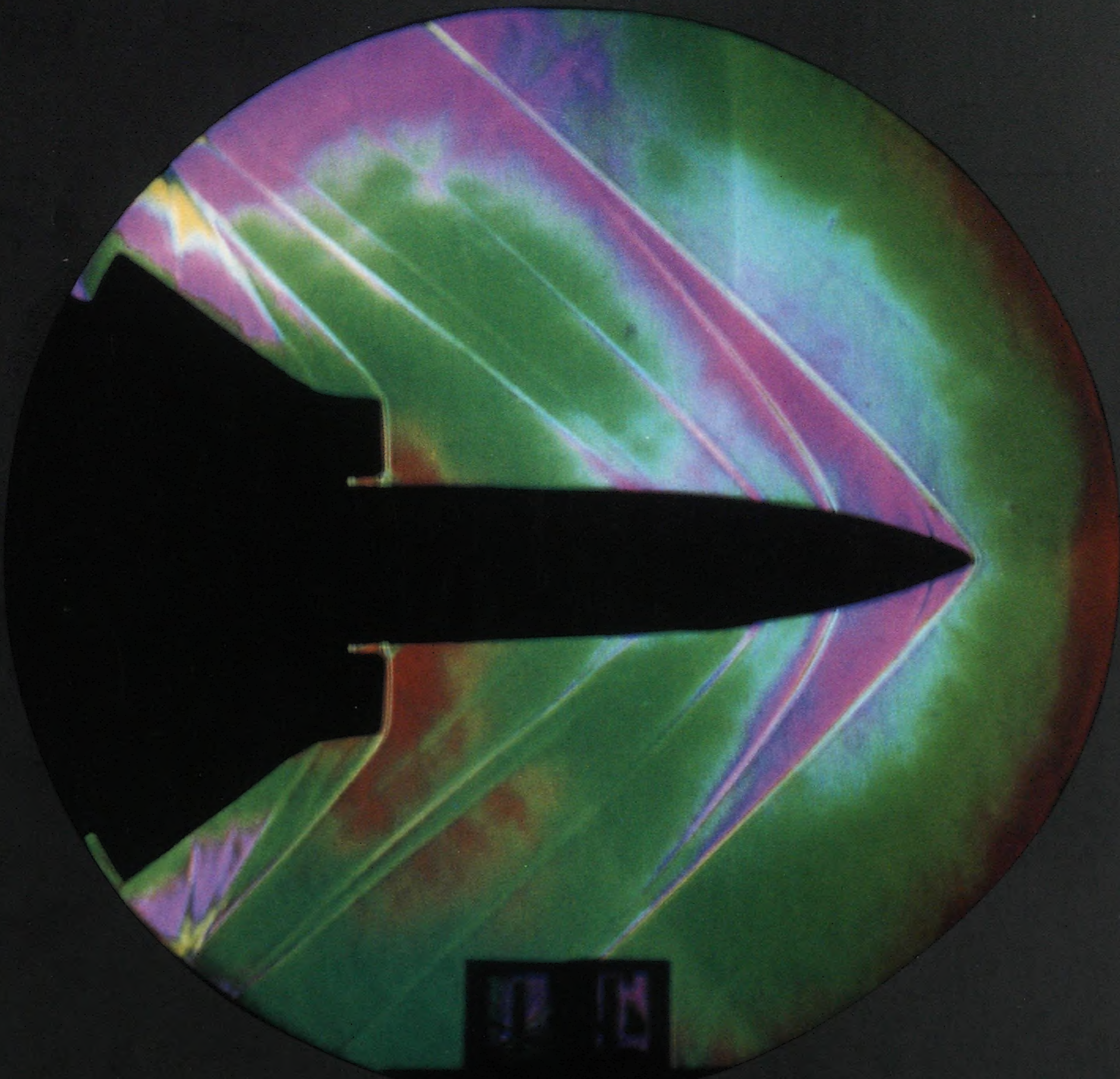

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Cover: Shock waves are made visible by Schlieren photography in the NASA Ames Transonic Wind Tunnel.

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Viewport

Space Station and Colonization?

Here is a simple quiz: Which nation, two decades ago, took samples of lunar surface material, brought them back to Earth, and landed vehicles on the moon to rove around and send back spectacular pictures? (a) The United States, (b) the Soviet Union.

If you picked the United States, you are only half right. The Apollo program, for all its amazing feats of landing men on the moon and returning them safely with a precious cargo of material from the first alien world ever visited, had a competitor. The Soviet Union's Lunokhod unmanned rovers spent weeks traveling across the lunar surface, transmitting back images. Other unmanned Soviet lunar missions took surface samples, loaded them on a rocket, and returned them to Earth.

Admittedly, the quantity of lunar soil retrieved by these rockets was only a tiny fraction of the amounts our astronauts brought back. But the first ounce counts for more than the next hundred pounds. A skilled mineralogist needs less than a gram to tell not only that the moon is made of rock rather than cheese, but also precisely what kind of rock is present, and how its atomic constituents differ from those of minerals on Earth.

So fragile is life in space that American astronauts could stay on the moon no more than two or three days each trip. Unlike Lunokhod, the manned Apollo mission required supplies of food, water, and air. Another danger was the potential occurrence of a solar flare—an enormous release of magnetic energy from the sun that hurls into space massive clouds of nuclear particles so energetic that they could penetrate the walls of a space capsule, irradiating the astronauts inside. Exposure to such an outburst can result in radiation sickness and death.

On longer trips in space, a host of medical, psychological, and social problems arise, most of which we have yet to understand properly—calcium loss in bones, muscle atrophy, depression from enclosure in a tiny capsule for months with a handful of others sharing the tedium.

This is where the space station comes in. Its primary purpose is to test the human capacity to live and work in space. Its living quarters and working spaces are designed around the long-term needs of astronauts. All other concerns are secondary.

But testing the astronauts' capacity for survival in space is important only if we are planning to have humans there for protracted periods. This leads us to ask "Why stay in space for any length of time?" We have repeatedly seen that satellites and spacecraft can be launched more easily by unmanned rockets than by shuttle astronauts. And for repair or retrieval missions, which conceivably might be done better by men than by unmanned machines, no lengthy stays are necessary.

The space station makes sense only if we are serious about colonizing space. Last year, on the 20th anniversary of the first manned landing on the moon, President Bush, speaking at the National Air and Space Museum, announced his plans for a manned outpost on Mars in the middle of the next century. In such contexts alone does the space station make sense.

For any purposes other than colonization, machines and robots outshine men. Think of the Viking craft, which in the 1970s conducted marvelously sophisticated experiments on Mars at one-thousandth the cost now projected for a first manned mission to that planet. And then there was Voyager, whose magnificent pictures of the giant outer planets and their rings and moons thrilled the nation year after year as the tiny spacecraft braved a 12-year journey no human could have survived.

As debates about the space station and its cost continue, we should be clear that we cannot justify the station as needed for astronomy, Earth observing, microgravity research, or any other experiments and applications. Its current price to the nation must be judged solely in terms of our wish to colonize space. Lunokhod, Viking, and Voyager all tell us: "Hands off! We are better able than you humans to do any job in space. The only thing we can't do for you is propagate your species."

—Martin Harwit is the director of the National Air and Space Museum.

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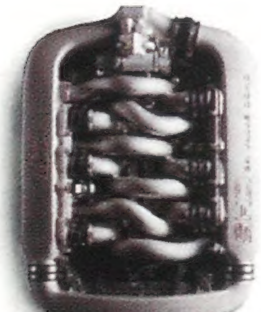

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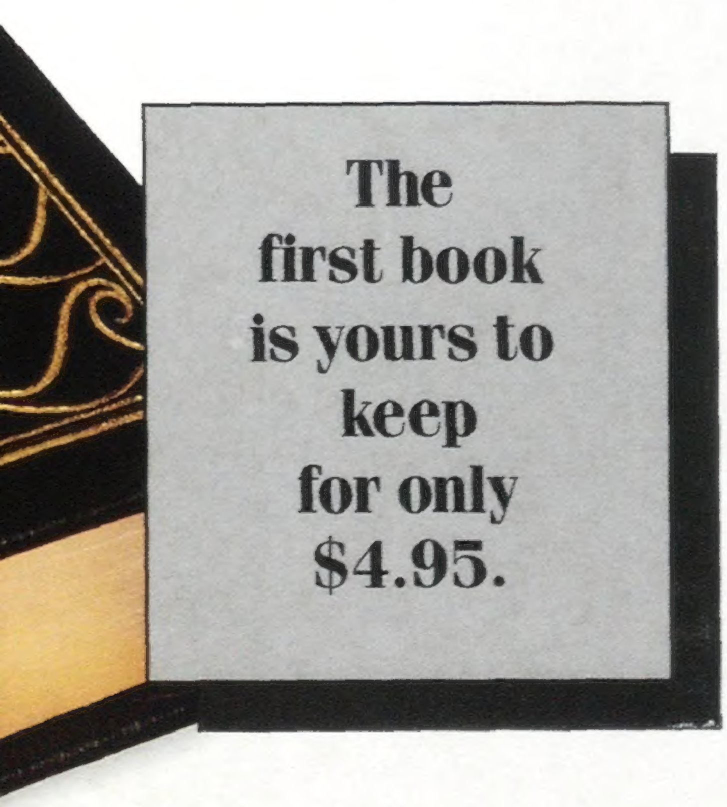

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Letters

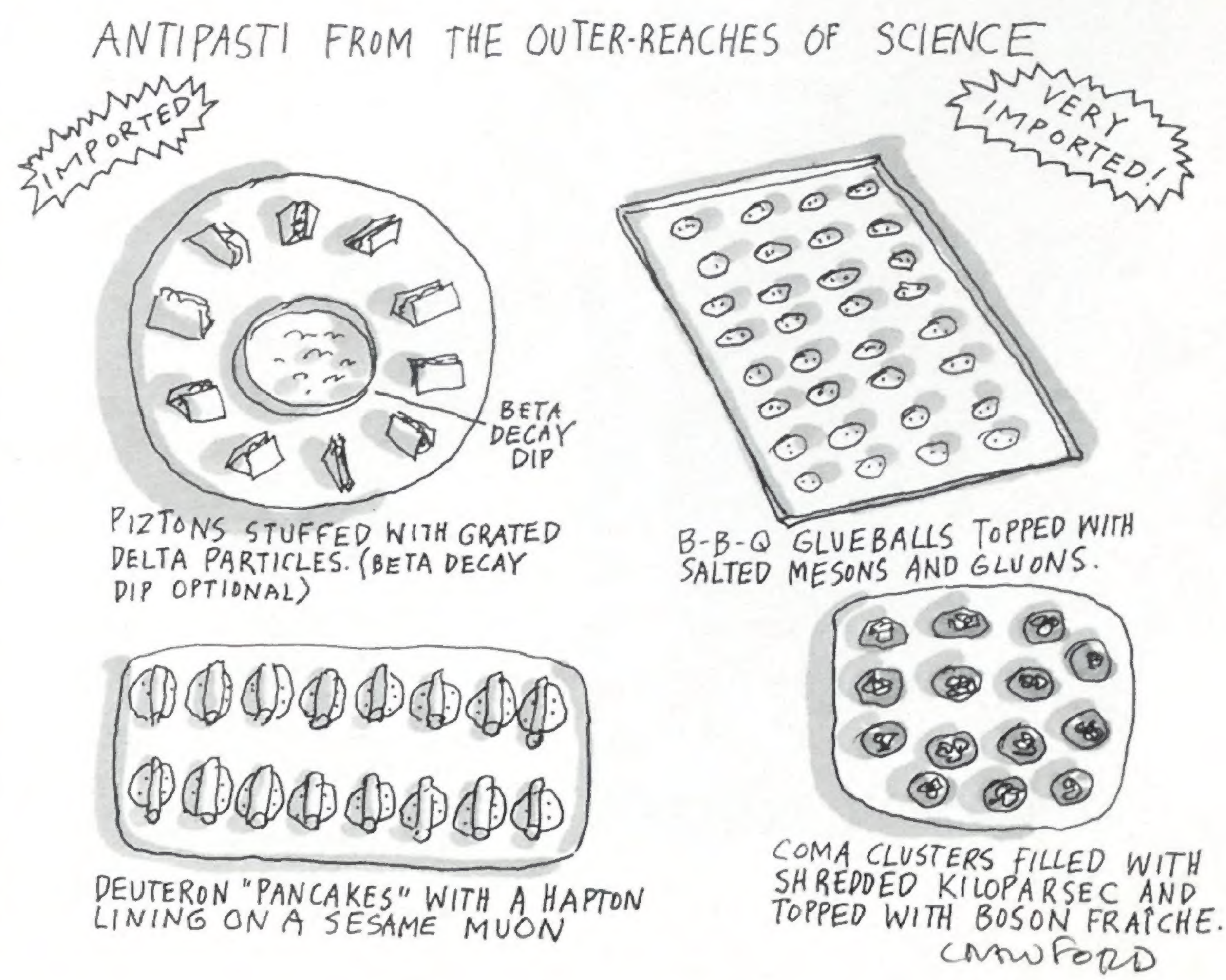
Keep Moralizing Out of Museums

Your presentation of aviation artifacts, "Treasures of the Air and Space Museum" (October/November 1990), is magnificent coverage of man's conquest of air and space. But you do a disservice to B-29 veterans by describing the *Enola Gay* as the centerpiece of a future "exhibit examining the controversial issue of strategic bombing." The effectiveness of strategic bombing has been debated since the days of Billy Mitchell. B-29s of the 20th Air Force brought Japan to its knees without a single American soldier setting foot on the Empire's homeland, but strategic bombing failed when B-17s and B-24s could not knock Germany out of the war. To use the *Enola Gay,* however, to examine the "controversial issue of strategic bombing" is simply a transparent excuse to moralize about nuclear warfare. A museum's role is to present history as it was, not as its curators would like it to be. President Truman had no moral problem with the use of nuclear warfare to save millions of American and Japanese lives, nor did the men of our military forces, poised to invade Japan at horrendous cost. And like it or not, nuclear deterrence did work through all those chilling years of cold war. The *Enola Gay* deserves to be displayed as a simple artifact of history and as a memorial and tribute to the men who flew it. Let morals and ethics be argued in seminaries and ivory towers by those who never heard a shot fired in anger.

Ben Nicks
9th Bomb Group Association
20th Air Force
Shawnee, Kansas

What's Going On Here?

I got the immediate impression that there is much more to Air Force chief of staff Larry Welch's statements on retiring the SR-71 ("The Blackbird's Wake," October/November 1990). His comments have a



very personal note, almost as if he were angry, and do not reflect the analytical reasoning usually used for making such an important decision. Did Welch ever fly as an SR-71 pilot? Did he ever apply to fly the SR-71? If he flew as an SR-71 crew member, how was he regarded by his peers? His comments are unusual and beg for clarification.

Renee E. McCall
Southlake, Texas

Editors' reply: We had heard the rumor that General Welch had applied to be an SR-71 pilot, so we asked him. Welch told us that he had never applied to be a Blackbird pilot. "My first association with the aircraft was as commander-in-chief of SAC," he said.

"The Blackbird's Wake" told only half the story. Many reconnaissance supporters believe that Welch was bound and determined to kill the SR-71 at any cost. Indeed, he seemed to have a personal vendetta against the program, providing inaccurate and misleading information to Congress and at one point ordering his subordinates to prepare plans to scrap all remaining Blackbirds. It was only after considerable pressure from Congress that he even agreed to permit NASA to use three of the retired aircraft for high-altitude research. At one point Welch even claimed to have been an SR-71 pilot. He later retracted the claim after being confronted with evidence that he had spent a grand total of three hours in the back seat of the SR-71B trainer and a day in the Blackbird flight simulator.

The real tragedy, however, is the loss of important intelligence gathering capabilities. Had the SR-71 been available last August, the Bush administration might have had notice of the impending Iraqi attack against Kuwait. ABC News reported in September that U.S. spy satellites lost track of eight divisions of the Iraqi Republican Guard as they were supposedly "pulling back" from the Kuwait border shortly before the invasion. Other sources have said that Secretary of Defense Richard Cheney turned down an urgent request by senior military leaders in the region to reactivate the SR-71 fleet in order to provide crucial intelligence when other overhead coverage was unavailable.

Doug Riggs
Alexandria, Virginia

Eliot Marshall states: "Thirty-two SR-71s were built and delivered to the military starting in 1966. Twelve have crashed in tests or accidents, but a crewman has never been lost." There have been three fatal

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accidents involving the A-12 and one fatal accident involving an SR-71A, which was lost near Tucumcari, New Mexico, on January 25, 1966. The pilot survived but the reconnaissance systems officer did not. What is remarkable is that the loss of life was not greater during the development of this magnificent aircraft.

Anthony Erich Grass
Burlington, Vermont

People Who Work in Glass Houses

On the same day that I read "NATO's Noise Problem" (August/September 1990) I was visiting the local nursery with its acres of glass greenhouses. We were discussing the finer merits of hanging plants when we were interrupted by the smashing sound shock of two Royal Air Force Tornados at just-above-my-head height. We all ducked—yes, indoors—and looked at one another and then up at the glass roof. Luckily, not one pane had cracked, although some showed the scars of previous visits. The head gardener, a fine bewhiskered gentleman in the old tradition, straightened up, looked back at us, and said, "Well, next time we'll be ready, won't we?" Then he turned back to the hanging plants. His reaction is a legacy of the Battle of Britain, which is still very much in the communal memory of those who live in the English countryside. Air defense still seems worth the noise and, yes, even the broken panes of glass.

Jed Falby
Devon, England

We Can Beat the Heat

Newton W. Miller's letter ("There Has to Be a Catch" October/November 1990) misstates the danger of solar power satellites. The frequency at which sunsats will transmit power to ground rectennas is in a "window" at which the atmosphere absorbs very little, certainly less than one percent. The matter is still under study, but atmospheric heating from the beam would be slight; it would almost certainly be negated if the greenhouse effect is decreased by the dwindling need for coal- and oil-fueled generating plants.

W. Paul Blase
Alexandria, Virginia

The Customer Is Always Right

I emphatically disagree with Allen R. Stubberud's description of Boeing's Inertial Upper Stage ("A Call for Quality," June/July 1990). Stubberud criticizes the reliability record of the IUS by stating that it failed on its first two launch attempts. This is simply incorrect. All spacecraft launched on the IUS have successfully been placed in proper orbit. It is true that an anomaly on the second flight in 1983 threatened the mission: the IUS lost control after providing 97 percent of the energy to achieve orbit. However, the satellite was ultimately put in the right orbit by NASA's ingenious use of the satellite's thrusters. All other IUS missions, including the first one, have been 100 percent successful.

The piece also says that an IUS costs $120 million per unit. Boeing's current cost to build IUS vehicles is less than half that and has been for years. The Boeing IUS has shown itself to be a cost-effective and reliable launch vehicle over and over again. But don't just take our word for it. Ask our customers at NASA and the Air Force.

H.A. DiRamio
Boeing IUS Program Manager
Seattle, Washington

Editors' reply: The first launch, on a Titan 34D, was successful. According to Jane's Spaceflight Directory, *the first IUS launched aboard a space shuttle, in April 1983, tumbled for hours after the second-stage burn until "increasingly desperate transmissions from all 3 control centers*

unexpectedly succeeded in regaining some measure of control." And on the second shuttle-*launched IUS, the first-stage motor underperformed. Thereafter, Boeing undertook a 20-month, $87 million modification program.*

Out With the Old, In With the New

I think it is only fitting that someone who has had the experience of walking on the moon should come up with an idea for getting humans to Mars ("The Mars Transit System," October/November 1990). As someone interested in being involved when we finally get there, I think Buzz Aldrin has something in his Cycler system. I hope the space community will take note and get the United States and the rest of the world to the next step in space exploration.

Cadet David N. Keener
U.S. Air Force Academy
Colorado Springs, Colorado

Buzz Aldrin's Earth/Mars transit system is an example of the kind of exciting advanced thinking this country's space program desperately needs. Aldrin throws away

many of the outmoded ideas of former days. When I visited the aeronautics and astronautics structures lab at MIT this summer, I was especially impressed by the work of three graduate students funded by a small NASA grant. They had built a 6′ x 6′ x 6′ tetrahedral truss structure to study how to stabilize large space-based radio telescopes. They chose a shape that used the naturally stable equilateral triangle and tetrahedron. They had a structures analysis program on a Sun workstation with which they compared the tetrahedral approach and the space station Freedom shape. It was sadly funny to watch the violent wrenching of the rectangular Freedom in its unavoidable oscillation modes. If three grad students with a few thousand dollars could figure this out, why can't NASA and its contractors with all of the billions this country has given them?

Robert E. Brooks
Los Angeles, California

Failed Humor

I ran across a picture of a "stretched" B-52 bomber in "The Postmodern Bomber" (Flights & Fancy, October/November 1990). I read the article carefully and found that this is the "B-3 bomber." I also looked closely at the picture and noticed four lines running down the photo. These lines obviously indicate that a section of the photo was repeated four times, giving the bomber the appearance of having 10 engines on each side. Was the photo presented to you as is? Or did you do this just to show what the B-3 would look like?

Tom Hess
Overland Park, Kansas

Editors' reply: We found the photo as is.

Lithuania's Loss

"Inside Star City" (June/July 1990) must be the ultimate proof of *glasnost*. Such a piece just a few years ago would have branded author James E. Oberg a bona fide CIA spy.

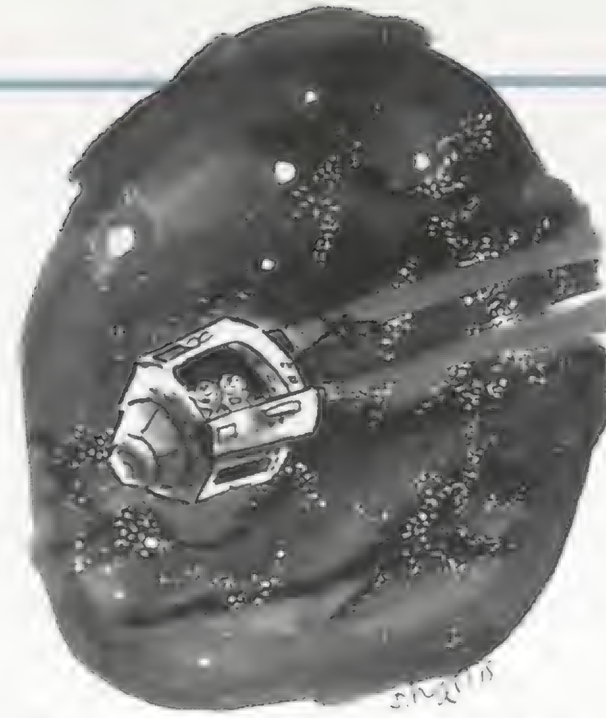
A cosmonaut not mentioned in the article, Rimantas Stankevicius, was in Seattle this summer flying a Sukhoi Su-27 at the Good Will Games and again at the Everett Air Fair. On September 9, 1990, Stankevicius, 46, was killed in a crash while flying at an airshow in Italy. To me his loss is most painful. He was my friend and countryman; both of us came from Lithuania. But beyond that, his death is a loss to humanity. He was that rare individual who came out of the Communist system totally untainted, a thoroughly noble human being.

Ina Bray
Seattle, Washington

Not Even For My Eyes

"The Eyes of England" (October/November 1990) made mention of the IFF (Identification Friend or Foe) device used in conjunction with radar. The device was very secret, and the IFF unit or black box contained an explosive charge activated by an inertial switch in the cockpit to prevent unauthorized access to the IFF circuitry in case of a crash. While in service with the U.S. Army Air Forces, I was briefly attached to a unit that had instructions to proceed directly to the scene of an airplane crash and either remove the IFF unit or make certain it had been blown to pieces. We were issued sidearms and told to maintain strict secrecy. In fact, it wasn't until years later that I learned what the IFF device was and what it did.

Ralph C. Williams
Winston-Salem, North Carolina



"If Einstein is correct, when we get back my car will have been double-parked for 320 years."

Air Sickness Bags, Also Known As . . .

I was amused to see your item on "motion discomfort containers" (In the Museum, August/September 1990). I have a similar collection in my office, complete with a plastic example of "discomfort" so that visitors will not have any doubt as to what these containers were designed to contain. I sometimes receive additions to my collection from people who were in my office only once and who remembered nothing about me or our conversation except the fact that I collect these souvenirs.

John W. Patterson
Richmond, Virginia

History Repeats

In "Lights, Camera, History!" (Above & Beyond, August/September 1990)

photographer Lee Battaglia wrote about his wild ride in a converted B-25 Mitchell bomber during the filming of *The Battle of Britain.* I know where that B-25 is today. It's based at Space Center Executive Airport in Titusville, Florida. Robbie Robinson of Ocala, Florida, lovingly restored the aircraft a few years back. The bomber was found derelict in a field; now it is one of the nicest B-25s around. Robinson and the aircraft's co-owners fly it to numerous airshows. And just as it did 22 years ago, it functions as a camera platform for the occasional photographer.

David G. Coleman
Indianapolis, Indiana

Corrections

The Me.109 had leading edge slats, not slots ("Sunset on *Adlertag,*" August/September 1990). Slots are open fixed spaces. Slats move in and out to change the leading edge and camber.

Martin Caidin
Gainesville, Florida

"Two Faces of Catastrophe" (August/September 1990) refers to Morton Thiokol as the "manufacturer of the solid rocket booster that exploded . . . ." Neither of space shuttle *Challenger*'s solid rocket boosters exploded. TV footage shows both boosters thrusting and moving along parallel trajectories *after* the contents of the shuttle's main fuel tank had ignited. Later, a range safety officer destroyed both boosters.

John R. Osborn
Lafayette, Indiana

In "The Mars Transit System" (October/November 1990), European mariners are said to have relied on "easterly winds to return them to their home ports." Easterly winds come *from* the east, blowing ships to the west. Wise mariners got out of the easterly trade winds and went north to catch the westerlies that would push them toward Europe.

Erik S. Buck
Dayton, Ohio

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News From Home

RON MILLER

For nearly three decades a swarm of Mariner, Venera, Voyager, and other probes have been roaming our solar system, capturing the likeness of every planet except two—Pluto and Earth. Pluto will have to wait another two or three decades, but at 12:35 p.m. Pacific time on December 8, Earth will join the list of worlds probed *en passant* by interplanetary fact-finders.

The flyby will be conducted by the Galileo space probe, which was launched aboard the shuttle in October 1989 and is ultimately headed for Jupiter, which it is expected to reach in 1995 (see "On the Road to Io," December 1988/January 1989). Originally Galileo was to get a direct boost to Jupiter via a Centaur upper-stage rocket, but after the 1986 *Challenger* disaster, the task of integrating the liquid-fuel Centaur with the shuttle was deemed too tricky, and the mission was redesigned to include a solid-fuel inertial upper stage, which many regard as safer. (Other safety concerns were raised about the plutonium power source that provides Galileo's electricity; several environmental groups filed an injunction to stop the launch, but the challenge was overturned in federal court.) Mission planners also mapped out a new flight path known as Venus-Earth-Earth Gravity Assist, or VEEGA, that will bring Galileo within 600 miles of our planet.

"Most of the principal investigators are very eager" to make observations during the first Earth encounter, says chief project scientist Torrence Johnson of California's Jet Propulsion Laboratory. "They want to get the instruments on and running and gain some experience" for the Jupiter observations.

The Earth flyby, however, will be more than a dress rehearsal. The radio science team, for example, will make new and extremely precise measurements of Earth's mass by tracking changes in Galileo's trajectory. Other scientists will use the probe to study Earth in wavelengths never before investigated. One instrument, the near-infrared mapping spectrometer, will examine the water content of the mesosphere, a region about 40 to 50 miles above Earth's surface. In the mesosphere, methane's hydrogen atoms recombine with

oxygen to form water. If the NIMS detects an increase in the mesosphere's water content, that would suggest that the lower atmosphere is experiencing an increase in methane. "It will be more evidence that things like the greenhouse effect are becoming more important," explains JPL's Bob Carlson, principal investigator for the NIMS.

Galileo's observations may also help resolve a question that has been igniting controversy among planetary scientists. Several years ago Lou Frank of the University of Iowa examined data from the 1981 Dynamics Explorer satellite and detected unexpected bursts of water in the upper atmosphere. Frank theorized that the water was being delivered by tiny ice comets. He proposed that these small bodies are constantly bombarding Earth, and that over billions of years they have supplied most of Earth's water. Frank's theory was attacked from every quarter, and although some observations seem to support it, most scientists still reject the idea. But if Galileo finds more water in the mesosphere than could be explained by increases in methane, the theory may gain adherents.

Another good place to look for evidence of tiny ice comets is around the moon, which should also be getting bombarded. Frank, principal investigator for Galileo's plasma detection instrument, says that if his theory holds up, the probe will show the entire Earth-moon system "sitting in a very tenuous water atmosphere . . . . Earth will be simply engulfed in it."

The moon will also get attention from other scientists. The geometry of the encounter will provide an excellent look at the moon's far side, as well as enable the mapping of mineral distribution across the moon's surface. These findings will be something of a sneak preview of the more extensive observations NASA hopes to make during the Lunar Observer program later in the decade.

In the same way, Galileo's Earth observations will presage some of the observations NASA plans for its Mission to Planet Earth program. Sweeping in from the night side, Galileo will pass over the isthmus of Panama and intensively image Australia and Antarctica. Because these bodies are well known from ground-based study, scientists will be able to determine how accurately the probe is depicting them. Says Dudley McConnell of NASA's solar system exploration division, "I think it will be interesting to look at the kinds of images we get of other planets and compare that with the kind of detailed knowledge we have about the Earth."

—Mark Washburn

LUFTHANSA

Lufthansa's Aging Ambassador

The corrugated craft parked on the ramp at New Jersey's Newark International Airport is a creature from another time. Once the mainstay of German passenger service, the tri-motor Junkers Ju-52 evokes a more adventurous and romantic era of air travel. Today, the Ju-52, owned by Lufthansa German Airlines, is triggering waves of Euro-nostalgia on a six-month tour of the United States to commemorate the airline's 35 years of service in this country.

Christened *Berlin-Tempelhof* for the airport where Lufthansa was founded in 1926, D-AQUI is one of only a handful of survivors of some 5,000 Ju-52s built between 1932 and 1952. It's the oldest aircraft in Lufthansa's inventory, but by virtue of its extensive restoration it's also the newest. "She has held up well and we are proud of her," says chief mechanic Helmut Brandes.

For its goodwill tour, Lufthansa wanted an aircraft that had not participated in the air war over Europe. D-AQUI was one of the few that had escaped conversion into a Luftwaffe light bomber. It served in Norway as a troop transport, air ambulance, and mail carrier during the war, then was returned to passenger use in Norway until 1956. D-AQUI was next sold to an Ecuadorian transport company, abandoned for six years in Quito for lack of spare parts, bought by a former U.S. Air Force pilot for $5,200 in 1969, and sold to aviation writer Martin Caidin six years later for $52,500.

Caidin refurbished the sturdy but homely airliner, named it *Iron Annie,* and toured the U.S. airshow circuit for seven years before selling the tri-motor back to Lufthansa in 1984. The airline spent 18 months restoring its prodigal son at its maintenance base in Hamburg.

"It's more than an airplane—it's a work of art," says Dennis Andrews, a catering supervisor at Newark who had a member of the touring crew autograph a tiny Ju-52 model. "I don't know who's having a better time, my three-year-old or his father," says Joanne Varco. But perhaps most affected by the Junkers' Newark visit is Alfred Weber, a 58-year-old Leipzig native. "It's just as I remember it, just so," he says, running a hand along the fuselage. "When I was a little boy, six or so, I went to the airport with my father and saw my first airplane, one of these. To me, this brings back memories of better times."

—Albert J. Parisi

Update

Wind Tunnel Overhaul

Five of the wind tunnels at NASA's Ames Research Center in California are undergoing a six-year, $160 million restoration and modernization program ("Into the Wind," February/March 1988). Several of the tunnels were built in the 1940s and '50s and have deteriorated due to heavy use, and much of the equipment is considered inefficient and antiquated. Shutdowns of the tunnels will force some aircraft manufacturers to test their designs in European facilities.

GARY BOGDON, ORLANDO SENTINEL

Holy SST!

"Some churches have steeples," boasts Ernie DeLoach, pastor of the New Life Assembly of God church in Kissimmee, Florida. "Ours has an airplane tail sticking out of the roof." The tail is part of the display of the sole mockup of the Boeing 2707-300 supersonic transport, which was placed in the building when the hangar-like structure housed aviation exhibits, not worshippers.

DeLoach became known as "the Plane Preacher" last August when he announced that the SST mockup would be sold to make room and raise money for the church's expansion in the former SST Air Museum. His call for a curator to save the airplane from the scrap heap made international headlines, and airplane aficionados responded in hopes of staving off salvage dealers who saw a scrap metal bonanza. "It's the only one of its kind and it ought to be preserved," says DeLoach. "When I realize that $1.2 billion was invested in this project and then I think about folks out there that need help—the homeless, the hungry—I feel like we need to save it somewhere. Let's put it into another museum."

The U.S. SST, proposed in 1966 as a rival to the French-British Concorde, was never more than a jetsetter's dream. Designed to cruise at Mach 2.7 and carry 250 passengers, the Boeing SST could have crossed the Atlantic in under three hours. But Congress, doubting the economic and environmental virtues of a supersonic transport, axed the program in 1971. Nebraska millionaire Marks Morrison bought the mockup at an auction for $31,119 and opened the SST museum.

Today, Sunday school sessions are held under the port wing inside the vast hangar that housed the museum from 1973 to 1981, when it folded. And even though the SST is in wretched shape—missing the other wing, dusty, dark, and devoid of any cabin furnishings—it still draws an occasional tourist, and that's what prompted DeLoach to save it.

"It's all torn up—it's almost a wreck," laments Robert Gwin, a retired airline pilot who would have flown TWA's first SST. "Maybe the fellow next door doesn't care if he ever sees it, but I know all the pilots would love it."

Late last October the church was still looking for a buyer. However, DeLoach reports that "we left the scrap dealers to the last, because I feel like this is American history."

—Beth Dickey

Update

HOTOL Booster?

British Aerospace's Horizontal Takeoff and Landing spacecraft may get a much-needed boost from the Soviet An-225 transport ("The HOTOL Man," December 1988/January 1989). BAe had announced last September that it would team up with the Soviet Ministry of Aviation to study the feasibility of launching the HOTOL from the huge Antonov aircraft. The new HOTOL strategy would employ Soviet-built conventional rockets rather than the Rolls-Royce air-breathing rocket engine designed by Alan Bond.

Robo-Wash

Cleaning an airliner is a labor-intensive part of routine maintenance. It takes 20 workers an average of four hours to hose, scrub, and mop a jumbo jet. Now a giant Japanese robot will make the job easier.

Last June the world's first automated jet wash debuted at Tokyo's Narita Airport. Developed by Japan Airlines and Kawasaki Heavy Industries over three years, Plane Wash is one of the largest robots ever constructed. "It looks like a huge Erector Set," says JAL spokesman Morris Simoncelli. The frame is nearly 300 feet wide, 330 feet long, and 86 feet high, big enough for the new Boeing 747-400s. It employs 16 computer-controlled washing units, 35 brushes, and 17 monitors.

It was the software rather than the mechanics that gave Plane Wash designers, engineers, and programmers migraines,

DAVID CLARK

says Simoncelli. The software must take into account the location of all the delicate protuberances—antennas and pitot tubes—on the various aircraft in the JAL fleet. Designers also had to build in a certain amount of flexibility to account for the very slight but inevitable warping of the fuselage over the aircraft's lifespan.

Though Plane Wash cost $13 million to develop, it will eventually save JAL time and money—it cuts wash time to 80 minutes and requires only five workers to monitor its operation. JAL washes its fleet at least once every six or seven weeks, since a clean aircraft is slightly more fuel-efficient.

JAL plans to market Plane Wash to other airlines for use at their maintenance hubs. "We'd like to have everyone buy one," Simoncelli says. "That's why we built it."

—Martin Morse Wooster

Airline passengers will soon view movies on personal video screens directly in front of them, make phone calls from their seats, and shop via credit card for in-flight merchandise from shopping channels. These and other features, including satellite-delivered stock market reports and up-to-the-minute news and sports highlights, are part of a new cabin communications and passenger entertainment system that will bring new levels of comfort and convenience to air travel. A team of Hughes Aircraft Company, Sony Trans Com Inc., and Hughes-subsidiary Avicom International is developing the system for the new Airbus A330 and A340 jetliners.

State-of-the-art air defense systems built by Hughes protect 37 percent of the free world's population. The Air Defense Ground Environment (ADGE) systems, designed by Hughes for 23 nations, network operations centers, ground-based and airborne sensors, surface-to-air missile bases, and air bases into real-time command and control systems. ADGE systems identify all aircraft approaching their nation's borders, display the aircraft's altitude, speed, and course, and electronically interrogate the aircraft to determine its identity. Future ADGE systems will include a new distributed architecture that will allow them to use more mobile and transportable elements, as well as off-the-shelf commercial computers, for more cost-effective operation.

A new fiber optic cable may open the door to interference-free, high speed communications. The metal-coated optical fiber was created by Hughes from long glass strands covered with an aluminum coating. These optical fibers withstand temperatures up to 400 degrees centigrade, can be soldered to eliminate the need for organic materials that could cause contamination, and exhibit long life and high reliability characteristics. Besides being used for point-to-point data communication, the new technology can also be incorporated in fiber optic sensors and optoelectronic hybrid circuits for use in space satellites, advanced fighter aircraft instrumentation, and automobile, aircraft and spacecraft engine monitoring.

A self-contained plasma source will help prolong the life of satellites in space. The source, part of the Flight Model Discharge System (FMDS), developed and built by Hughes for the U.S. Air Force, produces a dilute low-energy plasma cloud near the spacecraft's surface. This cloud effectively "grounds" the vehicle by forming a conductive bridge that electrically couples the vehicle's outer surfaces to each other and to the plasma of space. Without FMDS, electrical charges from ionized gases could build up on the spacecraft, causing arcing that could damage delicate electronic equipment.

Three-quarters of a billion dollars are on the way. And in 1990, Hughes Aircraft Company's Ground Systems Group is anticipating many more new contracts, in Air Traffic Control (ATC), Air Defense, and the commerical sector. These new programs have created excellent career opportunities for experienced and motivated individuals in systems engineering, software engineering, and test engineering. Appropriate background for work in the defense and intelligence communities is preferred in some positions. For immediate consideration, please send your resume to Hughes Aircraft Company, Ground Systems Group, Dept. 1343-T, PO Box 4275, Fullerton, CA 91634. Equal Opportunity Employer. Proof of U.S. citizenship may be required.

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TOM HUNTINGTON

"And In This Corner . . ."

The road to the Lockheed plant in Palmdale, California, is lined with signs arrayed sequentially like the old Burma Shave advertisements that once dotted America's highways. Altogether they read: "Air Superiority into the 21st Century."

That, at least, is what Lockheed is hoping to provide. Today, on a hot morning late in August, the company is rolling out the YF-22A, one of two candidates vying to become the Air Force's Advanced Tactical Fighter (ATF). An unusual co-venture among Lockheed, General Dynamics, and Boeing Military Airplanes, the YF-22A is competing with the YF-23A, a Northrop/ McDonnell Douglas production that began test flights a few days before today's coming-out party. At least Lockheed can now bill its rollout as quite possibly the last unveiling of a major U.S. fighter prototype in the 20th century.

Inside Lockheed's cavernous Plant 10, reporters, military brass, and Lockheed employees mill about the tables of pastries and coffee before settling onto folding chairs facing a podium. A wall of blue bunting hangs behind the podium; hidden behind it is the YF-22A. The top of a large American flag is visible above the curtain. On the high spotlight supports alongside, technicians lounge on folding chairs and read the newspaper, oblivious to the fuss below.

Except for the rollout paraphernalia, Building 10 is largely empty. There are a few P-3C Orions under construction, and eerie metallic clangs occasionally punctuate the buzz of conversation and portentous music being piped through the sound system.

Once the program begins, opening remarks are fairly brief—after all, people are here to see the airplane. General Robert D. Russ, commander of the Tactical Air Command, tells the crowd that "every rollout, particularly that of a fighter aircraft, touches me deeply." He also mentions that the Air Force's last fighter, the F-15, entered service in 1975 and will be more than 20 years old by the time the ATF enters service in 1998. "Not many of us here drive 1969 or 1970 automobiles," he says. Of course, an F-15 costs considerably more than a Buick, but he still has a point.

The YF-22A, Russ says, "is not just an airplane—it's an investment in freedom and security for all of us." It's more than that. Constructed under an $818 million Air Force contract, it's designed to be a jack-of-all-trades fighter. It will be stealthy. It will be capable of "supercruise"—going supersonic without afterburners. It will be highly maneuverable, thanks to thrust-vectoring engine nozzles. And its state-of-the-art avionics will employ super-fast integrated circuits.

Finally it's time. The PA begins to blare Wagner's "Ride of the Valkyries" as the blue curtains are hauled open. Bathed in spotlights, the huge American flag looming over it, the YF-22A is at last revealed. But it's all somehow a little anticlimactic. The airplane, which looks rather like an F-14 Tomcat with a water retention problem, is chained off to keep people from venturing too near, and it has been backed against the bunting to keep the engine nozzles out of sight.

This prototype, the first of two, is equipped with General Electric engines. The second will have Pratt & Whitneys, and the two engine systems will compete for the final slot aboard a production ATF. (Both companies will also compete over the YF-23A.) Once the engine preliminaries are over, the two ATF wannabes will have to tussle for the title, and the stakes are high. The Air Force plans to purchase 750 ATFs, and the Navy has expressed interest in nearly 550 to replace its F-14s. Although the bigwigs on the podium did some verbal tap dancing to sidestep a war of words about the competition, Lockheed chairman Daniel Tellep, in answer to a question about the YF-23A's head start in flight tests, did allow that "it's not he who flies first; it's he who flies best."

—*Tom Huntington*

CAROL PETRACHENKO—NASA/LANGLEY

An engineering model of a proposed "space taxi" is under study at NASA's Langley Research Center in Virginia. The HL-20 Personnel Launch System mini-shuttle, launched by a Titan IV, could service satellites, undertake observation missions during a three-day flight, or deliver up to 10 people or small payloads to a space station.

Update

Launch Pad Downgrade

Space Launch Complex 6, the never-used shuttle launch pad at Vandenberg Air Force Base in California, will be converted into a Titan IV and Centaur launch facility ("Spaceport West," April/May 1986). The Air Force succumbed to congressional pressure to convert the facility to an expendable-vehicle launch pad rather than build a brand-new one. The first launch is slated for 1996.

Air Force Lite

It took Jim Sanders 25 years to find out the color of the World War II Polish PZL-P11c fighter. While he waited, he founded a unique organization and publication—the Small Air Forces Clearing House and its quarterly journal, *small air forces observer.*

Sanders, a physics professor at a Naval postgraduate school in Monterey, California, publishes a journal that covers such topics as the use of Hawker Hunters in the Kuwaiti air force, the role of the Finnish air force in the 1939-1940 Winter War, early Dutch military aviation, the history of Mexican P-47s, and aircraft of the Icelandic coast guard.

Sanders started the Small Air Forces Clearing House in 1972, but *small air forces observer* didn't appear until 1976. "I called the International Plastic Modelers Society and asked for some information from their expert on the Polish air force," he says. "They asked me if I would like to be their expert." Sanders demurred, but he offered his services as a clearinghouse. Then he ran a notice in their publication. "I thought if enough people sent me $3, I'd do a magazine."

The first issue—still available for a modest $1.12—covered Ceylon's air force and the Spanish DC-1s, DC-2s, and Boeing P-26s used by the Philippine air force. Circulation has grown from an initial 100 to about 650 in 35 countries. "I lose about $100 an issue," Sanders says, "but I hope a small rate increase next year will take care of that." (A year's subscription is currently $9. Write to Sanders at 27964 Berwick Drive, Carmel, CA 93923.)

About half the readers live in the United States. Subscribers in Finland, Malta, Israel, Turkey, Latvia, Poland, the Netherlands, and Canada also serve as reporters on local activity, but "we've got nothing in Africa," says Sanders, "and Latin America has been hard to crack.

"I'm still not an expert, but I know who the experts are," he says. And who was finally able to nail down the paint scheme for the PZL-P11c? "It came from a member who went to a museum in Poland and scratched the paint on an airplane."

—*Thomas Wm. McGarry*

War and Remembrance

The Army Air Forces' 509th Composite Group, assigned the task of dropping the atomic bomb on Japan in 1945, numbered some 1,700 men. In the decades since Hiroshima they have kept in touch, and late last August, during one of their reunions, several hundred of them gathered in Wendover, Nevada, to unveil a monument

TIM KELLY

they had had built to honor themselves.

Originally established as a gold mining town and watering stop, Wendover was sufficiently isolated to serve as a training site where the men of the 509th could fly their B-29s and hone their skills before shipping out to the Pacific. The airfield is still there, catering to Cessnas instead of Superfortresses. The monument is only a few blocks away, across the street from the casino.

George Marquardt, pilot of an observation aircraft that overflew Hiroshima, had been in charge of the reunion and monument arrangements, which ended up costing over $50,000, "raised from members and friends of the 509th, Wendover people, and other contributors." Paul Tibbets, pilot of the *Enola Gay,* the aircraft that dropped the bomb on Hiroshima, had his own method of raising funds. He had written a book about the mission and recently developed a set of souvenirs, including *Enola Gay* coffee mugs and T-shirts, videotapes, and a color lithograph of the airplane climbing away as a mushroom cloud rose over the city. Sales had been brisk.

The monument and its dedication were productions of the 509th, not the Air Force or defense department. The honored guest was Hideaki Kase of Japan, a former advisor to two prime ministers. "I feel very comfortable being here," he said as the band played patriotic tunes. It was supposed to play the "Kimigayo," Japan's national anthem, but the sheet music hadn't arrived in time.

Then Tibbets stepped up to the podium. "People who attacked us for dropping the

bomb were engaging in communist propaganda," he said. "War means imposing your will on the enemy. We demanded unconditional surrender because we didn't start the war—but we were gonna finish it. Modern weapons are so powerful they cannot be discriminatory. We were bombing military targets and it's true that people were living near those targets, but they were as much a part of the war effort as the people who were wearing uniforms—even if they wore skirts." The invocation that followed seconded that emotion: "We thank God for the atom bomb, which was the bringer of peace."

Then it was time to unveil the monument, which was draped in plastic. A memorial at the University of Chicago marks the site of the first nuclear reactor—a free-form shape in bronze that looks vaguely like a fireball and vaguely like a skull. The style of the one in Wendover might be called Air Force Moderne. It features a B-29 atop an obelisk with the seal of the 509th at the base. It would look quite appropriate outside an officers' club. The seal bears a lightning bolt and the words "First Atomic Bombardment." A quote from Harry Truman is on the base: "The atomic bomb is too dangerous to be loose in a lawless world . . . we pray that (God) may guide us to use it in His ways and for His purposes."

If you're heading west from Salt Lake City some day, you might want to detour to see this piece of Americana. It's just up the road from a museum with photos of the jet- and rocket-powered cars that have set speed records on the nearby Bonneville Salt Flats. And Wendover is one of the few desert towns east of Reno that has a decent hotel.

—Tom Heppenheimer

Update

Blue-Ribbon Space Tomatoes

Tomatoes grown from seeds that spent six years in orbit aboard the Long-Duration Exposure Facility took first place at the Kansas State Fair last September ("What Goes Up . . . ," August/September 1989). Roger Hoefer entered the competition with his Rutgers strain of tomatoes at the last minute. "I couldn't believe it," he said. "I walked over there and they had the blue ribbon on them."

Prehistoric Stealth

He was a dapper man with small eyes, a mustache, and dark hair, which he parted slightly off center. In a photograph taken in 1910 at the Paris Salon de l'Aéronautique, he wears a business suit and a Mona Lisa smile while he poses in an airplane equipped with a 37-mm cannon. The primitive gunmount was the object of derision, but Gabriel Voisin would later help usher in the age of air power.

One of Voisin's airplanes, a Voisin VIII, is at the National Air and Space Museum's Paul E. Garber Facility, where it is being restored for the upcoming World War I aviation gallery. Although the glamour of fighters such as the Sopwith Camel and the Fokker D.VII took hold of the public's imagination, the bulk of air missions during the Great War were flown by observation airplanes and bombers like the Voisin. According to Karl Schneide, a member of the Museum's curatorial staff who is assisting with the Voisin's restoration, "It's probably one of the most important World War I types that we have."

The Voisin VIII was one of many airplanes built by the French designer, who became one of Europe's leading aircraft manufacturers. A year after the Wright brothers' flight at Kitty Hawk, Voisin and his brother established the first company on the continent to build an airplane. While everybody else was building wooden flying machines, Voisin was doing pioneer work with metal.

The Museum's Voisin is one of the oldest bombers in existence. With its fabric covering and primitive design, it looks more like the offspring of a baby carriage and a box kite than an ancestor of a modern bomber. "It's a peculiar-looking airplane," says restoration technician Karl Heinzel.

Although today's stealth technology was still another six decades off, in some ways the Voisin VIII represents the first stealth bomber, relying as it did on the cover of darkness to hide from the enemy. Capable of carrying 396 pounds of bombs, the two-seater was also one of the first strategic night bombers. For sorties over the Rhineland, a wind-driven generator charged a battery that provided electricity for cockpit lighting, landing lights, and firing parachute flares, which illuminated such targets as poison gas factories, railroad stations, and supply depots.

In spite of its primitive appearance, the Voisin VIII offered a variety of innovations. "It's got a lot of really unique advanced features," Heinzel says, listing wheel brakes, dual overhead cams, dual ignition, carburetor heat, and a dry sump lubrication system. A Peugeot 220-horsepower engine gave the airplane a top speed of 75 mph. Rapid strides in aircraft design, however, made the lumbering Voisin obsolete before the end of the war.

The restoration is scheduled to be completed next spring. Heinzel has recently had his hands full with the Belgian linen that will cover the wings. Among the router, table saw, and other carpentry tools being used to restore the fabric airplane sits one seemingly incongruous item: an ancient Singer sewing machine. "It's probably the most important tool in the shop for this airplane," Heinzel says.

"It's going to be a real showstopper," says Karl Heinzel of the nearly restored Voisin VIII.

CAROLYN RUSSO

The Vengeance Weapon

There's an apocryphal story that when V-2 missiles were first launched against London, V-2 designer Wernher von Braun observed that the German rocket had worked perfectly—except that it landed on the wrong planet. The fact is that the V-2, the first large liquid-fuel rocket, was at the time also the largest and most advanced missile in the world. Last month the Museum opened a new exhibit designed around its V-2. The exhibit's goal, according to curator David DeVorkin, is "to place the V-2 into its proper historical context—why it was built."

Today the rocket is remembered by many as the vehicle that took the first step into space. But "V-2" stood for Vengeance Weapon-2; as DeVorkin points out, "it was built literally as a military weapon." Thinking otherwise could be dangerous. According to another story, the SS had von Braun arrested on the pretext that during a party he had speculated about space travel. It took his military commander's

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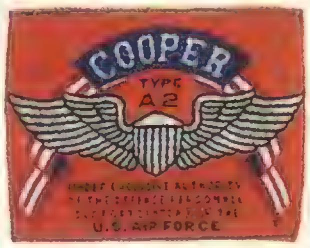

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It took about five minutes from launch for a V-2 missile to arrive at its target.

intervention to win von Braun's release.

"Hitler's weapon," as the rocket was dubbed, traveled four times faster than sound and had a range of better than 150 miles. The 46-foot-long missile weighed 28,000 pounds and consisted of three sections: a nose that housed a one-ton warhead and control mechanisms, fuel tanks containing liquid oxygen and alcohol propellants that produced 56,000 pounds of thrust for about a minute, and a tail section, which included the rocket engine, turbopumps, and control surfaces.

Between September 6, 1944, and March 28, 1945, more than 3,000 V-2 missiles were launched from Germany and its occupied territories. The rocket's major targets included London and Antwerp, and altogether V-2 missiles killed more than 7,000 people. Ironically, producing the weapon killed a far greater number: according to DeVorkin, perhaps 10,000 to 20,000 concentration camp prisoners lost their lives while laboring under terrible conditions to build the rocket.

Following the war, captured V-2 rockets were shipped from Germany to the United States. The Soviet Union and the United States also scrambled to collect Germany's top rocket scientists; in some respects, this marked the beginning of the Missile Race. At the White Sands Proving Grounds in the New Mexico desert, V-2 rockets became the first large sounding rockets to carry scientific instruments into the upper atmosphere (see "Richard Tousey and His Beady-Eyed V-2s," June/July 1986).

Descendants of von Braun's V-2 would one day make it possible to land on another planet, launching the Viking probes that landed on Mars in 1976. But it is the Saturn V, the rocket that took us to the moon and is arguably derived from von Braun's ideas, that is perhaps his greatest legacy. In the Museum a model of the Apollo 11 lunar landing vehicle stands less than a hundred yards from the V-2, a rocket that brought out both the best and worst of mankind.

—*David Savold*

Artifacts

MARK AVINO

The National Air and Space Museum was established in 1946 as the National Air Museum, but the Smithsonian Institution's collection of aeronautical objects began many years earlier with Chinese festival kites. Twenty of them were donated in 1876 by the Imperial Chinese government, which had exhibited the kites at the Philadelphia Centennial. The colorful kites are now on display at the Museum's Garber Facility.

Museum Calendar

Except where noted, no tickets or reservations are required. Call Smithsonian Information at (202) 357-2700 for details.

New IMAX Film *Blue Planet* features spectacular footage of Earth filmed from the space shuttle. Shown five times daily in the Langley Theater. Call for admission prices.

New Film Series Robots will be the theme of the Museum's 1991 science fiction film series. Every Friday, beginning January 4. Langley Theater, 8:30 p.m.

December 6 General Electric Aviation Lecture: "Riding the Mustang." Stefan A. Cavallo, civilian test pilot for the North American P-51 Mustang. Langley Theater, 8 p.m.

December 13 Legacy of Strategic Bombing Lecture: "Some Lessons Learned from History." McGeorge Bundy, national security advisor to Presidents Kennedy and Johnson. Langley Theater, 8 p.m.

January 5 Monthly Sky Lecture (rescheduled): "The Vanishing Night." Geoff Chester, NASM. Einstein Planetarium, 9:30 a.m.

January 17 General Electric Aviation Lecture: To be announced. Bob Hoover, stunt pilot and airshow performer. Langley Theater, 8 p.m.

January 31 Wernher von Braun Memorial Lecture: To be announced. Ruben F. Mettler, chairman emeritus of TRW, Inc. Langley Theater, 8 p.m.

Planning a Smithsonian Visit? The Associates' Planning Packet is yours for the asking. Send a postcard to Associates' Reception Center, Smithsonian Institution, Washington, DC 20560, or call (202) 357-2700. Hearing-impaired visitors can use TDD and call (202) 357-1729.

Museum Hours Most of the Smithsonian museums are open 10 a.m. to 5:30 p.m. daily. (For most recent information, call 202-357-2700.) The Smithsonian Castle, which has reopened with the new Smithsonian Information Center and Associates' Lounge, is open 9 a.m. to 5:30 p.m. daily.

"Midair!"

As a test pilot in the 1950s and '60s, I'd flown fast airplanes—the supersonic F-100 as well as the F-104, F-106, F-107, and B-58, all of which were capable of Mach 2. I'd also flown big airplanes—the Boeing 707, the B-47, the B-52, the British VC-10, and the Vulcan bomber—but the XB-70 was a big jump. In 1964 it was the biggest and heaviest aircraft in the world and one of the fastest.

Designed as a replacement for the aging B-52 strategic bomber, the North American XB-70 Valkyrie could operate at Mach 3 at 70,000 feet or above with a range of nearly 7,000 miles. To withstand the 600-degree skin temperatures incurred at that speed and altitude, it was built primarily of stainless steel honeycomb and titanium. The unique configuration included a canard control surface, a movable windshield that streamlined the nose at cruise speed, and giant variable-geometry inlet ducts that adjusted the position of the shock waves and fed air to the engines at sea-level pressures. Also, the XB-70's wingtips could be lowered 65 degrees in flight for high-speed stability.

When the Johnson administration cancelled the production contract, the two XB-70s that had been built became research vehicles. After completing the primary milestones of the original XB-70 contract, North American turned to less demanding data flights. On June 8, 1966, we planned to do airspeed calibration runs and a sonic boom run to measure the intensity

of the boom at a given Mach number and altitude. Then we were to join up with an F-104, a T-38, an F-4, and an F-5 for publicity pictures for General Electric, which had made the engines on all five aircraft. The flight seemed like a good opportunity to give Major Carl Cross an XB-70 indoctrination flight. He and Joe Walker, NASA's chief pilot at Edwards Air Force Base in California, were next in line to get checked out in the airplane.

Fitz Fulton was scheduled to fly the XB-70 that morning, but he had a conflict. I was asked to fill in, with Carl as copilot. I wasn't present at Carl's briefing, but I knew he'd spent most of the previous day in ground school. He'd also been taught how to use the escape system, which consisted of two modules that encapsulated the pilot and copilot prior to ejection.

I arrived at Edwards about 6 a.m., attended the preflight briefing, and went out to the airplane with Carl. He seemed calm, but if he was anything like the rest of us he probably had a few butterflies. The XB-70 was awesome the first time you climbed aboard.

USAF (2)

A publicity flight turned into a nightmare when the F-104 (second from right) hit the XB-70 wingtip, then struck the twin vertical tails and exploded.

We soon finished the data runs and started trying to rendezvous with the other airplanes, including Clay Lacy's Learjet, which was carrying the photographer. Joe Walker in the F-104 was the first to join up. We flew up the Owens Valley, just topping the clouds. We turned east to stay low and slow enough for the chase plane and set up a racetrack pattern on a line between Mojave and Barstow. Carl took the controls for a lap around the pattern just to get a feel for the airplane, and then I took it back.

We were headed east, straight and level at 30,000 feet, when we heard a loud *bang* followed immediately by shouts of "Midair! Midair! Midair!" over the radio. Neither Carl nor I said a word, probably because we heard rather than felt the bang and were both listening intently. The chatter on the radio was coming fast—I heard the words "You've lost your stabilizer but you're doing okay." I was sitting there transfixed, trying to figure out who had the problem. I knew it was close because I had heard it. (It wasn't until I heard the tape later that I heard Joe Cotton in the T-38 call our aircraft identifier.)

After about ten seconds the XB-70 started to roll slightly to the right. When I tried to correct the movement I got an immediate clue as to who had the problem. The airplane yawed violently and continued to roll. It felt like the giant airplane was trying to snap-roll. "Bail out! Bail out!" the radio crackled.

My immediate fear was that the forward fuselage would break off and that we wouldn't be able to eject due to the G loads. Mel Apt's tragic experience in the Bell X-2 in 1956 flashed through my mind. He had fired the nose capsule off, but it was unstable. Pinned inside by the high G

forces, he had been unable to complete the ejection sequence.

Fortunately, the XB-70 fuselage held together, but during the second roll the left wing came off. From that point on I would be hard-pressed to describe the maneuvers the airplane went through. But just before I ejected I realized we were in a flat spin.

When Joe Cotton commanded us to bail out, I was trying to apply engine power on the right side to counteract the yaw, but it was already obvious that the airplane was out of control. By the time it had completed the first roll I had pulled the ejection system "encapsulate" handle. But my elbow was outside the capsule when I pulled the handle, and when the ballistic charges that rocked the seat back into the capsule and sealed the doors fired, the upper clamshell door came down on my arm. The doors did not close because my elbow was sticking out. If I fired the ejection rocket now, my arm would be cut off.

I could see Carl's head moving on the other side of the cockpit but I couldn't reach the microphone button, and since my doors could not close, the voice-activated "hot" mike had not been triggered. There was no way I could talk to him. It was an eerie feeling, needing to talk to each other, the chase planes, and all the support people on the ground but suddenly unable to communicate. There's no way to help your partner and no way he can help you. And though encapsulation was the only way out, for some reason Carl did not encapsulate. If I could have talked to him maybe I could have helped.

As the airplane gyrated down through the overcast I wrestled with my arm problem and became less and less aware of what was going on around me. Everyone has limitations under pressure, and by then I'd about reached the limit of my ability to act. When I finally got my arm loose I had no idea how far we had fallen. I only knew I had to get out—*now.* I squeezed the trigger and fired out of the airplane with the capsule doors open.

Suddenly it was very quiet. Then there was a big *whoosh* as the airplane went by just below me in a spin. I thought the next time around it might get me, but my parachute opened and the airplane dropped away. Several seconds later I heard a terrible WHOMP as it hit the ground.

The capsule clamshell door had a small window at the top. The next thing I saw through it was the cactus on a hill about 100 yards away. I realized I was coming down too fast but I had no time to worry. When I hit, it sounded like a metal garbage can full of bricks landing on a concrete sidewalk after a three-story drop. It hurt worse than anything I've ever felt.

Out of control, the XB-70, streaming fuel, tumbled into a flat spin.

The capsule hit the side of the hill with such force that I made heel prints in the metal floor and partially bent the seat to my buttocks. The weight of my body tore the seat off the mounts, which may have saved my life—calculations later showed that the peak load on the capsule at impact was 44 Gs. The failure of the seat structure reduced the load on my body to 33 Gs. I didn't break any bones, but I sure did bruise a lot of things.

When the dust settled the capsule was lying on its right side and the doors had sprung open an inch or two. I figured I really must have mangled my arm because I couldn't move it. I guess I was a little disoriented—the reason I couldn't move it was because I was lying on it.

Pilot Al White ejected before the aircraft slammed into the desert floor.

USAF (2)

I got the top door open and was trying to crawl out when the T-38 went by. I waved as best I could. It was great to see that they knew where I was and that I was alive. I got out, stood up, and pulled my jacket out, but I had trouble getting it on. Even though it was a late spring morning in the desert I was getting very cold and stiff—so stiff that I couldn't sit back down. I pulled the parachute around me for warmth.

Eventually the Aeromed helicopter arrived. As it slowly came over the hill the downwash from the blades started to inflate the chute. I thought I was going to be airborne again and I really wasn't in the mood for it.

The next thing I remember was those wonderful Aeromed guys hauling me up the hill on a stretcher. The helicopter ride to the hospital was not the most comfortable I've had, but things were looking up.

We later learned that the horizontal tail of Joe Walker's F-104 hit the turned-down wingtip of the XB-70. The collision pitched his airplane up and rolled it across the top of the XB-70's fuselage. The F-104 crashed into the Valkyrie's twin vertical tails and exploded. Walker was killed instantly. The XB-70 was left with no directional control or stability. For reasons unknown Carl did not eject. Aside from the loss of two valuable airplanes, the real tragedy was the loss of those two fine men.

By September I was back at work and on flying status. The other XB-70 had been laid up for some modifications to the inlet system and the escape system. It would not fly again until early 1967, and then only Air Force and NASA pilots could fly it. There was nothing in the immediate future for me at North American, so I accepted an assignment with TWA.

I have very strong feelings about the XB-70. It was a marvelous airplane, like no other. I'll always regret that it never got the chance to prove how good it really was and that I couldn't have helped with that proof.

—*Al White*

Out Where?

"A reporter's search for the truth—that is, what *actually* happened, is always a rough journey," writes Howard Blum in *Out There: The Government's Secret Quest for Extraterrestrials.* We may all be in for a rough journey. Blum alleges that in 1987 the Defense Intelligence Agency set up a top-secret panel to investigate UFOs, a startling report given that the government claims it quit investigating UFOs in 1969. Blum names only one member of the UFO Working Group—its director, a Colonel

RON MILLER

Harold E. Phillips—but says there were 17 members when the still-active group was formed, including Army and Air Force generals, DIA scientists, and National Security Agency officials.

It's hard to say if *Out There* will have the pop-cultural impact that Whitley Strieber's *Communion* did in the late 1980s, but one thing seems certain: it will be in our faces for a while. Blum entered the noisome world of "ufology" with more substantial journalism credentials than most; he's a former investigative reporter for the *New York Times* and the *Village Voice* and the author of books on Nazi hunting and the Walker spy family. *Out There* got good reviews in mainstream publications like the *New York Times* and *Entertainment Weekly* and is being turned into a TV miniseries by David ("Roots") Wolper, which makes it likely that your UFO-believing friends will wave Blum under your nostrils like an ammonia capsule. "Wake up, buster," they'll cackle, "and smell the reality."

So you need to know: is this reality? Blum-debunking started quickly. Last September Mr. Skeptic himself, Philip J. Klass, squared off with Blum on the Oprah Winfrey show, a match that resulted in more heat than light. Klass is sometimes criticized for narrowmindedness in his campaigns against UFO believers, but this time he appears to be right.

The first off-putting thing about *Out There* is its tone. Blum writes in a style he calls "literary journalism"—a blend of self-involved first person and "novelistic" accounts of events he didn't witness. Sometimes he lopes into Shirley MacLaine country. At one point he quotes a source who says this UFO business is so secret, "Even the government doesn't know what it knows." He follows that with classic gobbledygook: "For this was, I was now coming to believe, a tale that might have sprung forth from the dark imagination of a Beckett. Only now, the real-life actors do not simply wait impotently for Godot, but, resigned and helpless, they lament that this mysterious yet fulfilling stranger has indeed come—yet it doesn't matter. A malicious clique of the powerful has conspired to keep this miracle a secret."

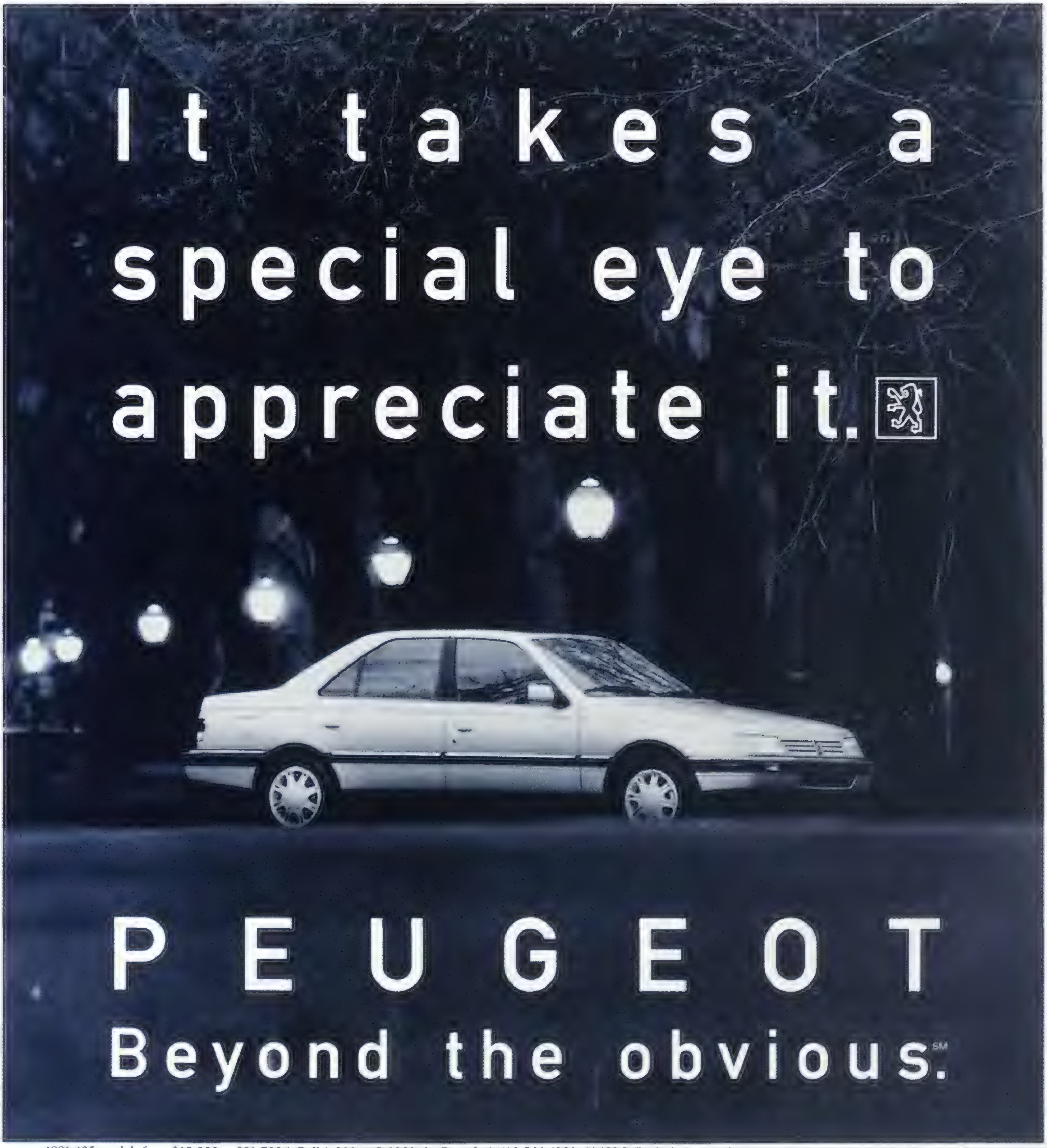
Facts, of course, are what matter. Blum insists that every word in *Out There* was verified, even the novelistic details. In one episode, set in a West Virginia diner in 1959, Frank Drake, a pioneer in the search for extraterrestrial intelligence, gets a lunchtime lecture from a senior colleague who "had raised . . . a lone french fry toward Drake as if it were a truncheon." Even the fry, Blum guarantees, was fact-checked, and he frets that readers will lose sight of his rigor as they skip through his vivid prose: "Would readers understand that seemingly casual details . . . even the greasy french fry . . . were rock-solid facts excavated from mountains of research?"

I'm having trouble understanding that, because what Klass objects to are precisely those rock-solid facts. And we're not talking about the arcane, ultimately unprovable details of most UFO debates, but Big, Checkable matters. Take, for example, Army colonel Harold E. Phillips. Klass' attempts to find him were fruitless. In a review of *Out There,* published in the *Los Angeles Times,* Klass says Army records show one officer with that name—a lieutenant colonel who retired in 1984, three years before Blum's Harold Phillips was assigned to direct the UFO Working Group. Blum says his Colonel Phillips graduated from the University of Southern Illinois. Klass has a letter from the university that says its records show no such person. Blum says he visited the offices of Project Blue Book, which, he writes, are "lovingly preserved" at Wright-Patterson Air Force Base in Dayton, Ohio. Not true, says Klass, who quotes a Wright-Patterson spokesman to the effect that the room no longer exists (it was swallowed up in a remodeling project).

All of which Blum might answer with a knowing "Yes, they would tell Klass that." I guess; Blum didn't return my phone calls. But I did connect with one featured player in the book, former *New York Times* reporter Seymour Hersh, a man with a reputation for exactness. His testimony was not Blum-helpful. In *Out There,* Blum recounts how he approached Hersh for advice after receiving a tip from a National Security Agency official that "a panel of hotshots" was investigating UFOs. He visited Hersh's "office in the National Press Club" to ask for help in following up on the information. (Um, I think he means the National Press Building.) "Sy went from zero to sixty in about a second," Blum writes. " 'Get out of here, Blum! . . . You think I give a damn about that sort of craziness?' But two days later Hersh called back: 'Blum? Hersh here. You're right—the government is as crazy as you are. They do have some kind of committee that's looking into all that kooky stuff.' "

Judging by my interview with Hersh, Blum got it half right. Yes, Hersh is hot-tempered, but what he's angry about is how Blum quoted him. "All I did was tell him there was some ESP stuff going on in the Pentagon. I didn't say anything about UFOs!"

—Alex Heard



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How you see the Peugeot 405 S depends on how you look at it.

A glance will probably note the leather seats, but miss the two densities of foam used to eliminate seat springs which transmit road vibration. It might take in the six-speaker anti-theft AM/FM cassette stereo system, but miss the hydraulic-powered anti-lock braking system.

A more discerning eye will see Peugeot's passion for building cars which do not sacrifice any one element for another, but aim to provide the optimum balance of all aspects of the car.

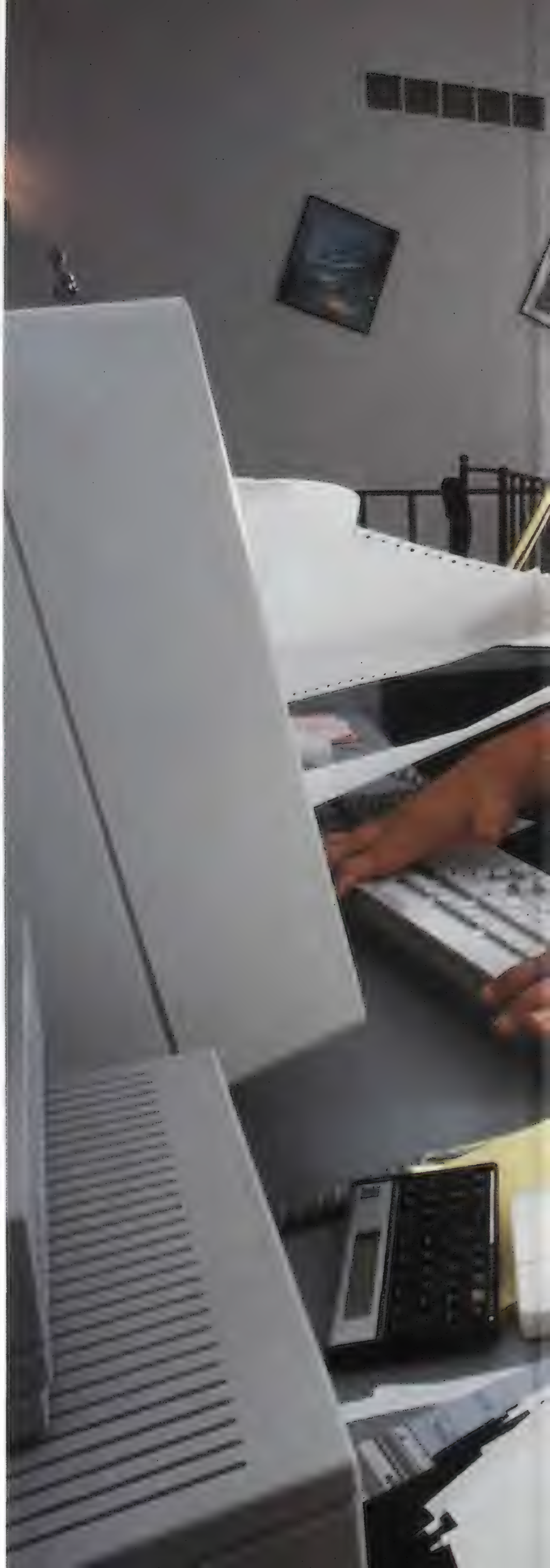
Something which, if you haven't yet experienced, you are certain to appreciate.

John Roncz, the shaper of wings to come, can really make the ol' computer fly.

Wing Man

by David Noland

Photographs by Robert M. Lightfoot III



"Let's go commit lift," says John Roncz as he strolls toward a sleek white twin-engine business jet parked on a ramp in the California desert sun. Lift—the force that keeps an airplane aloft—is Roncz's Holy Grail. The 42-year-old self-taught airfoil designer has spent 15 months hunched over the keyboard of a personal computer in his Granger, Indiana home, refining the shape of the craft's wings, tail, and air inlets. On this warm December day, he is eager to see it fly and get the data that will tell him how well he's done.

This business jet prototype—the Triumph Model 143, called Tuna by the people who designed and built it—is the latest design to emerge from Burt Rutan's Mojave, California skunkworks. A prolific designer of homebuilt aircraft, Rutan is best known for the *Voyager*, the long-winged craft that Burt's brother Dick and Jeana Yeager flew around the world in 1986 without refueling. Rutan also designed the turboprop Beech Starship and built the rigid sail for the 1988 America's Cup-winning catamaran *Stars & Stripes*. But it was Roncz, working as a consultant to Rutan, who crafted the innovative airfoil shapes that were essential to the success of those projects. "Without John Roncz," says *Voyager* pilot Dick Rutan, "we would have landed in South America."

Renaissance man Roncz's creativity surfaced early. A violin prodigy at five, he turned to the piano at 10 and was competing internationally a year later. He attended a tiny private high school with a program for gifted students, where he demonstrated his ingenuity by distilling 50 gallons of whiskey

Tuft-testing—taping yarn to a wing to examine airflow—confirms Roncz's design intuitions (above).

Months of intensive labor on the Starship (below) landed Roncz in the hospital, but the airplane flew on time.

in the science lab. In his teens Roncz came across *Theory of Wing Sections,* a classic aeronautical engineering textbook published in 1949. "I'd always been interested in airplanes, and it looked like it would be fun to play around with the airfoils in the book," he remembers. "But I took one look at all the math and decided that life was too short. In those days all we had was slide rules. It was very frustrating."

Roncz breezed through Notre Dame, studying everything from particle physics to Egyptian hieroglyphics and learning eight languages ("I have a funny talent for languages," he says with a shrug). After earning a bachelor's degree in government and international studies, he worked as a carpenter in a mobile home plant, then briefly turned to abstract and surrealistic painting as a profession. Eventually he started Gemini Sales, a small company that supplied steel to the metal-stamping industry. In

DOUG SHANE

his spare time Roncz learned to fly, bought a Rockwell 112A single-engine airplane, and flew cargo in twin-engine Cessna 310s and Piper Navajos at night to accrue flight time.

In 1975—prehistoric times in personal computer chronology—Roncz built a crude computer from a $300 kit. "When I finished the computer," he recalls, "I said, Okay, now what do I do with it?" Remembering the tedious aeronautical equations that had frustrated him as a teenager, he wrote a program to solve them. Freed from the drudgery of the slide rule, he went on a number-crunching spree. Virtually ignoring his steel business except for occasional frantic bouts of managing, Roncz spent countless hours at the keyboard, trying to visualize how air moves around an airfoil and learning to express

Roncz's airfoil designs include propellers, here being examined after computer-controlled milling.

those movements numerically. Roncz was immersed in the complex science of computational fluid dynamics—the computerized study of liquids and gases in motion that has streamlined the design process (see "Number Crunchers," below). "I still don't know why it fascinated me so," he says. "Why do some people decide they want to play the flügelhorn? There's just no accounting for taste, I guess."

Roncz was particularly fascinated by laminar-flow airfoils. Their ultrasmooth surfaces keep skin friction low and encourage smoothly layered airflow, thereby decreasing drag and increasing an aircraft's efficiency. On conventional airfoils, laminar flow breaks down at the point where it has completed only 10 to 20 percent of its journey from the leading edge of the wing to its trailing edge, a distance termed "chord." As soon as the flow becomes turbulent, it creates drag.

Roncz's numbers showed that with a very smooth and rigid wing surface and the proper airfoil shape, laminar flow

Number Crunchers

$$\frac{\partial \rho v}{\partial t} + \frac{\partial(\rho uv + \tau_{yx})}{\partial x} + \frac{\partial(\rho v^2 + \sigma_y)}{\partial y} + \frac{\partial(\rho vw + \tau_{yz})}{\partial z} = 0$$

Despite its aura of mathematical wizardry, airfoil design was, until recently, largely empirical. "It was mostly trial and error," recalls Ray Hicks, an aerodynamicist who learned his trade in the NASA-Ames wind tunnels in California during the late 1950s. "You'd come up with a shape, put it in the tunnel, then get some wax and a file and try again."

Not that airflow formulas didn't exist. The Navier-Stokes equations, which completely describe fluid flow, have been the bedrock of fluid dynamics since 1845 (example above right). These nonlinear partial differential equations "could theoretically describe every motion of a leaf falling to the ground," says John Roncz. But they are fearsomely complex and beyond the abilities of even today's supercomputers to solve under all conditions.

It wasn't until the turn of the century that even rough calculations became possible. In 1904 German physicist Ludwig Prandtl hypothesized the existence of the boundary layer—a thin layer of air that, due to friction, adheres to a surface rather than flowing over it—and later showed that the assumption of a boundary layer could simplify the Navier-Stokes equations and enable approximations that described an attached airflow.

But the approximations broke down when the boundary layer separated from an airfoil surface, which happens all too often in the real world. Frustrated airfoil designers would lay down their slide rules and head for the wind tunnel for trial-and-error testing. For years, "airfoil design" consisted mainly of choosing a shape out of a catalog of tunnel-tested designs.

A light at the end of the tunnel appeared in the 1960s with the debut of fast, powerful commercial computers and the birth of computational fluid dynamics. Computers could replace the equations with approximations, advance them in space and time, and run the massive calculations required to produce a numerical description of airflow by breaking a surface into thousands of "points" and calculating fluid motion equations for each one. Aerodynamicists and programmers at NASA-Ames Research Center, among other labs, began writing programs to simulate more complex geometries and larger airfoil sections. "Some of the wing section designs we cranked out on that old IBM 7090 worked in the wind tunnel, so we just kept going," says Hicks. By the mid-1970s computers and code-writing were advancing so quickly that some aerodynamicists predicted wind tunnels would soon be obsolete. A single simulation that in 1957 would have taken 30 years and $10 million in computer time to complete could now be done on a Cray-1 in 30 minutes for $1,000.

But today even the best CFD programs can't accurately predict the maximum lift of an entire wing or the drag of an entire airframe. "We can do pretty well when the boundary layer is attached, but separated flow is still a problem," says Antony Jameson, an aerospace engineer at Princeton and a leading CFD theoretician. Only in the simplest cases can a computer quickly answer the engineer's perennial question, *What happens if I change this?* "You can't treat CFD as a black box that spits out aircraft designs," says Preston Henne, formerly manager of advanced aerodynamics at McDonnell Douglas. "The results have to pass a judgment test. The human designer is still very much in the loop." Or as Ray Hicks puts it, "Don't throw away the wind tunnels just yet."

could be maintained across 50 or 60 percent of the chord line—"No great revelation in the lab," he says, "but I was pushing for real-world application."

Roncz found his opportunity in Burt Rutan, whose futuristic designs typically employ a canard—a forward-mounted horizontal stabilizer and elevator that looks like a small wing and usually replaces the conventional tail surface. In 1980, Roncz, who had never met Rutan, brashly sent him his computer analysis of the canard airfoil on Rutan's Long-EZ.

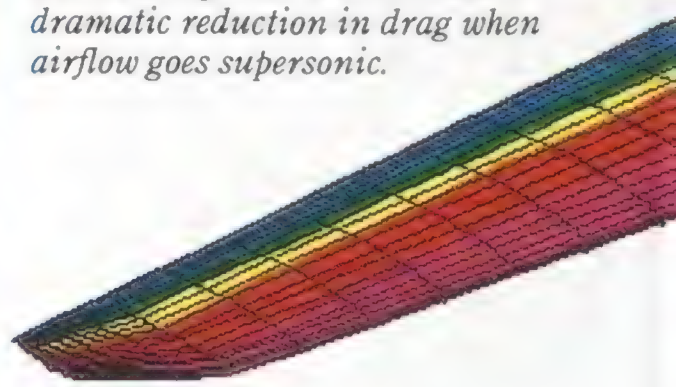
No airfoil expert, Rutan sent Roncz's analysis to Bruce Carmichael, a specialist in small laminar-flow airfoils at Rockwell. "Burt asked me if this guy Roncz was on the right track," says Carmichael. "I looked over his stuff, and not only was it on the right track, he was about two years ahead of the state of the art for small laminar-flow airfoils."

"I called John up," Rutan recalls, "and found this jovial, brilliant individual at the other end of the phone." Rutan asked Roncz to look over some airfoils he was thinking about using on a powered glider called the Solitaire. Roncz put the airfoil numbers into his computer, saw some problems, and sent Rutan his analysis, along with some airfoils of his own design.

In the meantime, Rutan had been having problems with the Long-EZ. In rain, water droplets would disrupt the laminar flow over the canard, triggering a loss of lift that tended to force the nose

GEMINI TECHNOLOGIES INC.

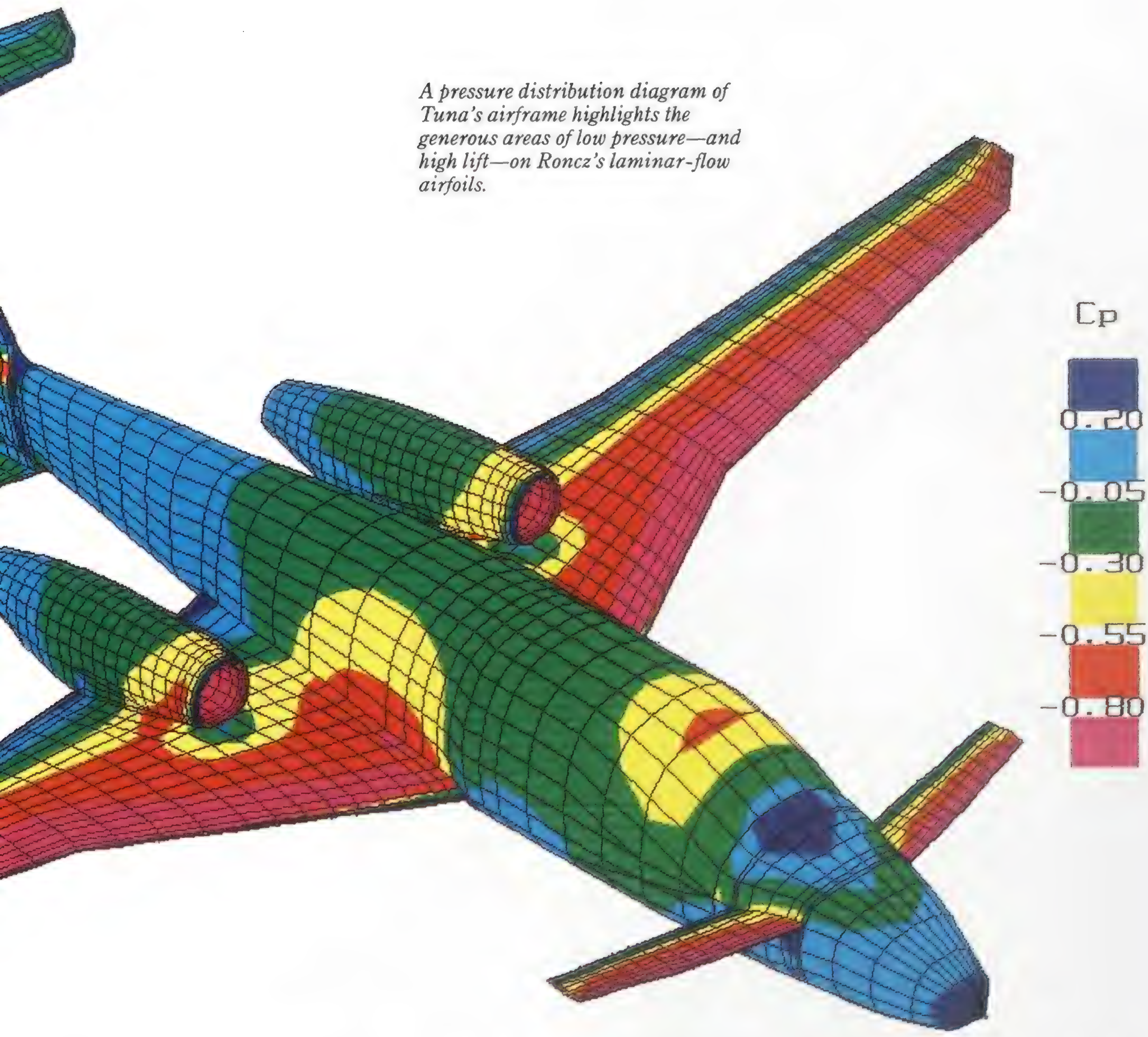
Tuna's numerous airfoils (left) began as a series of numbers on Roncz's computer screen. Above: Wind tunnel measurements comparing a standard NACA wing with Tuna's show a dramatic reduction in drag when airflow goes supersonic.



ROBERT TORRES

down. Rutan found that grafting a Roncz wing-root airfoil onto the Long-EZ canard solved the rain problem. It also kicked off a Roncz-Rutan partnership that is still going strong.

Their first major collaboration was an 85 percent-scale prototype of the Starship, built in great secrecy for Beech Aircraft. Roncz worked nearly nonstop for nine months to get the airplane flying in time for the 1983 National Business Aircraft Association show in Dallas. By this time he had a second, more powerful homebuilt computer, but personal computer modems, which transmit data over a phone line, were not commonly available. So Roncz



A pressure distribution diagram of Tuna's airframe highlights the generous areas of low pressure—and high lift—on Roncz's laminar-flow airfoils.

spent hundreds of hours reading seven-digit numbers that described airfoil shapes—almost a million digits in all—over the phone to a Rutan assistant, who entered them into an Apple computer that translated them into plots. By the end, he says, "we were literally crazed with fatigue, and I almost died from peritonitis." Roncz spent 10 days in the hospital, but the prototype flew on time, performed as promised, and was the hit of the show.

Realizing Roncz's value to his company, Rutan tried to bring him to Mojave. Roncz, who is single, declined. "I could never live in a town that didn't have at least two symphony orchestras," he told *Sport Aviation* magazine at the time. (South Bend, a few miles southwest of Granger, meets his quota.) Managers at Beech, impressed with his Starship work, offered him a job heading up all the company's aerodynamics divisions. Again he refused. "I just couldn't work in a big company like that, where an engineer can get stuck working for years on a landing gear trunnion."

Roncz's contributions to the design of the round-the-world *Voyager* aircraft made his name a household word in aerodynamics circles. The Roncz-designed airfoil in *Voyager*'s canard had a lift-to-drag ratio—the measure of an airfoil's efficiency—of 132:1, meaning that for every 132 pounds of lift the canard created, a mere one pound of drag resulted. (A standard airfoil's lift-to-drag ratio is only 110:1.) In a frenzied four-day number crunching marathon, Roncz went on to design new shapes for *Voyager*'s metal propellers that increased efficiency by four percent, which Dick Rutan calls "an astonishing improvement in a business where people offer to sacrifice their grandmothers for a two percent improvement."

Roncz also solved *Voyager*'s bug problem. During its nine-day flight the aircraft would encounter numerous insects, whose splattered carcasses would seriously degrade the aircraft's perfor-

Roncz entertains fellow pilot Sciona Browne with an uplifting classical composition.

mance and range by disrupting the laminar airflow across the ultra-smooth wings. "John did a crash course in entomology," recounted Dick Rutan in the book *Voyager.* "[He] figured out what types of bugs we would find all around the world, how many at each altitude, how many per square meter, how big they were."

Roncz then tailored the wing's leading edge so that the pressure wave it created would cause small bugs to glance off the top of the wing while larger insects would glance off the bottom. When *Voyager* landed at Edwards Air Force Base in California after its epic flight, police held back the crowds while Roncz inspected the wings for bugs. He found dozens of streaks but only three carcasses.

By the time Tuna started taking shape on Rutan's drawing board, Roncz had settled on airfoil design as his calling and had transformed Gemini Sales into Gemini Technologies, an aerodynamics consulting service. He had augmented his two homebuilt computers with three store-bought models, a modem, and sophisticated software that simulated the pressure distribution on a three-dimensional airframe.

Once Rutan decided on Tuna's basic layout—low wing, twin engine, T-tail, small forward wing—Roncz began defining the numerous airfoils in the control surfaces, wings, canard, engine inlets, and horizontal and vertical stabilizers. "The first step is an intuitive guess," he says, fingers dancing on the keyboard as he demonstrates the process. When he enters his best guess for a shape, the computer responds with a pressure distribution plot. "Pressure drives everything else," he says. "It's the cause of all the nasty things." Rows of numbers scroll by on the screen, a language that Roncz can instantly visualize as drag. Then a pressure distribution graph appears. "Of course you don't get a good curve the first time," he says. "So you try another guess—maybe put a little cusp here or fatten it up there—and see how that affects the curve." A few taps on the keyboard. More rows of numbers. Another graph. "I'll spend weeks polishing," he says. "Not many people have the patience for this kind of work. Really, what it all boils down to is experience, intuition, and endless drudgery."

Roncz breaks up the drudgery by moving to another keyboard—that of the 2,138-pound Baldwin grand piano that dominates his living room. ("I know exactly how much it weighs because I had to design the floor to support it.") Eyes closed and head bobbing gently, he executes a powerful rendition of Rachmaninoff's Prelude number 12. "For years, all I would play was Chopin," he says. "But now I'm really into the Russian guys. They're so passionate and complex and intellectually challenging."

When grounded in Granger, Roncz pilots an aerodynamically clean Mazda Miata.

Back at the computer keyboard, Roncz eventually came up with a wing for Tuna that displayed a rather startling characteristic in wind tunnel tests: at Mach 0.71, when the airflow over the top of the wing begins to go supersonic, the drag dropped by 30 percent—just the opposite of the sudden and dramatic rise in drag usually observed at that point. Roncz believes he's figured out a new way to delay the formation of shock waves, which typically send drag numbers skyrocketing when airflow goes supersonic. "I found a loophole," he says. With Tuna, Roncz predicts, shock waves and the resulting rise in drag won't occur until the airplane hits Mach 0.73, compared with the Cessna Citation's shock-wave onset at Mach 0.625. "So far, it's as close to perfect out of the box as anything Burt's ever built," he says with undisguised pride.

But every airplane has its developmental bugs, and today Roncz is in Mojave to help Rutan solve one of them. Standing on the ramp gazing up at the odd forward-swept horizontal stabilizer on Tuna's T-tail, which is festooned with pressure sensors, he explains, "We're getting a high-speed buzz at about Mach 0.66. I think it's probably a shock wave at the intersection of the fin and stabilizer. But we need pressure data to make sure."

Unfortunately, Roncz won't get his data this time. On today's first test flight, the right landing gear door hangs open slightly, and as Tuna accelerates past 287 mph at 25,000 feet, a strut breaks and the gear pops out of its well. Tuna's pilot stooges around trying to get the gear down and locked, but when fuel runs low, he has to come in to land. With the useless right gear dangling, the airplane touches down on the runway, settles on its right wingtip, and skids to a grinding halt. No one is hurt and damage is minor. But Tuna won't be flying for a while, so Roncz heads back to his keyboards in Granger, where numerous aerodynamic projects wait.

In the past decade some 20 airplane designs have flown with Roncz's airfoils. "The main advantage I have is that I've never taken a single course in aeronautical engineering," he says. "As a result, I've had to figure it all out myself. You understand things better that way."

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Amber Waves

Using plows as paintbrushes, American farmers turn fields into fine art.

Text and photographs by Georg Gerster

All over the world farmers draw with plow, harrow, and harvesting combine, and paint with the colors of their crops. As land artists they have no equal, and the palette and patterns of American agriculture, in particular, seem inexhaustible. While coaxing bounty from the earth to feed the United States and other nations, farmers coincidentally offer up a visual feast for the eyes of an airborne viewer. To such a one the agrarian landscapes between the Hudson and Sacramento appear as a vast open-air museum, with hundreds of thousands of tableaux on display, most of them a square mile in area and framed by bordering roads. Some of these exhibits rival the mystery of prehistoric ground drawings; others conjure up the tumultuous abstractions of modern canvases. And all of them incessantly change with the seasons, being blessed with both transient and timeless splendor.

American farmers, needless to say, do not

Most farm art is functional: at left, piles of California orange peels dry before being added to livestock feed. Stan Herd's clover field still life is art for art's sake. The tractor near the bottom of the vase provides scale.

Open areas cut into a field of lentils in eastern Washington state will hasten ripening. The band at top has already been harvested.

harbor artistic intent. They are land artists without really trying—usually. A few exceptions of planned field graphics just prove the rule. Neighboring counties where large-scale farmers fly to work or into town in their own planes have had contests in land art as well as in crop yields. In the late 1930s, a farmer in Bent County, Colorado, plowed a mosaic of circular strips into the native grass on a full square-mile section: a helper, acting as a center pivot, reined him with a rope as he was going around. He had no justification for his creations other than that he liked doing it. For the past two decades this particular field

In a California field, sheep graze on alfalfa (below). Some farmers believe sheep eat more weeds than crop, improving yields. In Washington state, sprinkler arms of center-pivot irrigation systems create green oases a half-mile in diameter amid sandy soil mixed with ash from Mount St. Helens (bottom).

has been conventionally block farmed, with total disregard for the former artistic layout, but flying over it I could still discern ghostly circles, like old script underneath newer lettering on a reused parchment. And in 1988 an Iowa farmer planted a section of corn in the shape of 60-year-old Mickey Mouse. The

In Texas, a farmer has roughened his field to keep the soil from being swept away by the wind (left). Oklahoma also has a history of losing topsoil. The owner of the land shown below hopes the patterns he has plowed in the soil will prevent the wind from doing further damage.

A springtime bloom of rape protects soil in an Idaho field. The plant is seeded in the summer to provide protection during winter and spring.

Photographer Georg Gerster spent over a thousand hours in the air to take the photos for Amber Waves of Grain.

awareness that airborne viewers are looking down on a farmer's work inspires not only aesthetic impulses. Instead of sending telegrams to Washington, American farmers sometimes inscribe their fields. I AM BROKE MR. REAGAN! wrote an Illinois farmer, in one of the longer and more polite messages crying out to the heavens. The texts prompted in the 1980s by the farm crisis more often consisted of four-letter words. At times, indignation even speaks without words. During World War II a farmer in Gray County, Kansas, was driven to despair by the noise of Flying Fortresses carrying out training flights from two nearby air bases. His exasperation obviously got the better of his judgement, for he plowed a huge swastika in his field. The provocation did not fail to command the attention of the pilots. And the protesting farmer was lucky that their only retaliation was to bombard him with even more noise.

But enough of artistic fancy and fits of temper. The average American farmer is a man of reason, and his unintentional art derives solely from measures aimed at higher or at least sustained yields. I found it gratifying that the most stunning productions in this open-air museum originate in the resolve not to mine but to husband the soil. Stewardship of the soil, born of the near catastrophe of the "Dirty Thirties," has enlivened the writing on this land with the graphic vocabulary of conservation farming. Perhaps no farming area in the U.S. is visually more exciting than Lancaster, Berks and York counties in Pennsylvania; none, I am told, is more productive.

Donn Owens had piloted me on one of the last sorties for this project. After our return to the North Las Vegas airport he drove me back

Water runoff from this Oklahoma rangeland is directed to control dams. The amount of soil in the water testifies to the damaging erosion.

to my hotel. Dusk fell; the glitz and razzamatazz of gambler's paradise beckoned me with myriad lights. Luminous but utterly devoid of numinosity, the city was an improbable backdrop for what Donn, born of an Oglala Sioux mother, was to tell me. While a student at Washington State University in Pullman, he had come across some of my aerial views of the Palouse country in eastern Washington. "I was profoundly moved by them," Donn recalled. "My heritage, I guess. Your pictures are imbued with an almost Indian sensitivity for the land." Native Americans, he said, bemoan the broken bonds with the land. "Whenever the ancient guardian spirits of the land—invoked by whatever means, be it even a photograph—reappear and speak to us, we resonate."

Donn's words suffused me with the satisfaction that comes with a wonderfully soft touch-down: a long quest above had attained its goal below.

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SCOTT HIGHTON

by George C. Larson

Collision Insurance

It's called TCAS II–and it may help make the skies even friendlier.

On the morning of September 25, 1978, Pacific Southwest Airlines flight 182, a Boeing 727 descending to land at San Diego's Lindbergh Field, collided with a Cessna 172 that was practicing instrument approaches at the airport. All 135 people aboard the airliner and both men in the Cessna were killed, as were seven people on the ground. It was a nightmarish disaster, and not just because it involved a midair collision and an ensuing crash into a residential neighborhood. What's really haunting is the number of factors that suggest it shouldn't have happened at all.

During its approach to Lindbergh, PSA 182 had been advised of the Cessna's location by both San Diego Approach Control and the airport control tower. The crew acknowledged seeing the Cessna. The sky was clear, visibility extended for 10 miles, and not only were both aircraft talking to air traffic control facilities, but controllers also had a new technology to alert them to traffic conflicts: the symbol "CA" (conflict alert) had flashed on their radarscopes next to the symbol for each aircraft, and an aural warning had sounded. But the controller thought PSA 182 had the

WIDE WORLD

Cessna in sight, and once the 727's crew acknowledged seeing the other airplane, it became their responsibility to "maintain visual separation."

According to the conversation on the Boeing's cockpit voice recorder, a few seconds after the tower issued its warning the crew apparently lost sight of the smaller airplane. Less than a minute later the airliner struck the Cessna from behind.

The San Diego disaster raised fundamental questions about how air traffic information should be managed. Airplanes flying today follow two vastly different procedures. When visibility is good, it's up to the pilots to maintain separation from each other. When the weather is bad, air traffic controllers assume responsibility for separating the traffic under their control. Under both sets of rules, the most critical bit of information—the position of air traffic—has been confined to radarscopes on the ground. Federal Aviation Administration regulations clearly state that a pilot has final command and responsibility for the airplane, but that's like driving down a highway with only a verbal description of where the other cars are.

That situation should change with the introduction into the U.S. airline fleet of a new device called a traffic alert and collision avoidance system, or TCAS (pronounced "TEE-cas"). All airliners with more than 30 seats must be equipped with the system in order to fly in the United States after December 31, 1993.

Before World War II, the system for separating airplanes was so primitive that today it seems downright scary. In the few places where there was any traffic coordination at all, pilots simply reported their positions relative to radio fixes or known points on the ground—or at least their best guess. If two flights were approaching the same point in the sky, they observed some minimum interval between the times of their passage or used different altitudes on designated airways.

In 1956 a Trans World Airlines Super Constellation and a United Airlines DC-7 collided over the Grand Canyon, an accident that led to the expansion of radar surveillance over virtually the entire continental United States. The radar consoles at air traffic control facilities on the ground became the primary tools for coordinating traffic, with information or instructions passed to pilots by radio.

The airline industry wasn't convinced that ground-based air traffic control and radar surveillance ought to be the sole guarantors of safety, and in 1955—well before the Grand Canyon incident—it had begun to search for an airplane-based system to alert crews to potential collisions. What the airlines wanted was not so much an alternative to ATC radar as a backup system. The conceptual building blocks were identified fairly early in the game. John S. Morrel of Bendix established that the key measurement must be the time to the computed point of collision, not the distance separating the conflicting aircraft. It also became clear that collision avoidance maneuvers between two aircraft couldn't be left to chance, so the systems would have to communicate and coordinate their actions. And whatever command or advice the system issued to the pilots, it had to be completely unambiguous. Pilots should never have to wonder *What do I do now?*

After studying the options, the airline industry and the FAA decided to take advantage of radar transponder beacons, which had been installed in airliners so they could be tracked and identified by ground-based radar more easily. Each time an ATC radar beam swept past a transponder-equipped airplane, the transponder squawked a burst of radio code. ATC assigned each airplane its own coded identifier, which enabled computers to track a given flight in a swarm of traffic.

Later, the transponder was linked to the altimeter so the airplane's altitude could also be displayed automatically on radarscopes. Yet another development, a discrete address beacon system, allowed the transponder to reply only when it was addressed—literally to speak only when spoken to. Airplanes now had the potential to exchange information and coordinate maneuvers without interrupting other transponders. A collision avoidance system based on beacons, called BCAS, had the advantage of being piggybacked on equipment already in wide use, so a substantial portion of the aircraft fleet would be covered

In 1978, PSA flight 182 struck a Cessna and crashed to the ground in flames (above). New anti-collision devices for airliners are intended to prevent any more such accidents.

Captured on a long-exposure photograph, airplane landing lights dramatically illustrate the crowding around airports (opposite). Under such conditions, crews could lower the range of the TCAS II equipment and de-clutter their screens by eliminating distant aircraft.

without a huge expense for the airlines.

Critics began demanding—especially loudly after PSA 182—that the FAA get on with it and impose some rule requiring an airborne anti-collision measure. They said the FAA had an institutional bias against *any* such technology because collision avoidance systems implied lack of faith in air traffic control—the largest and most powerful function of the agency.

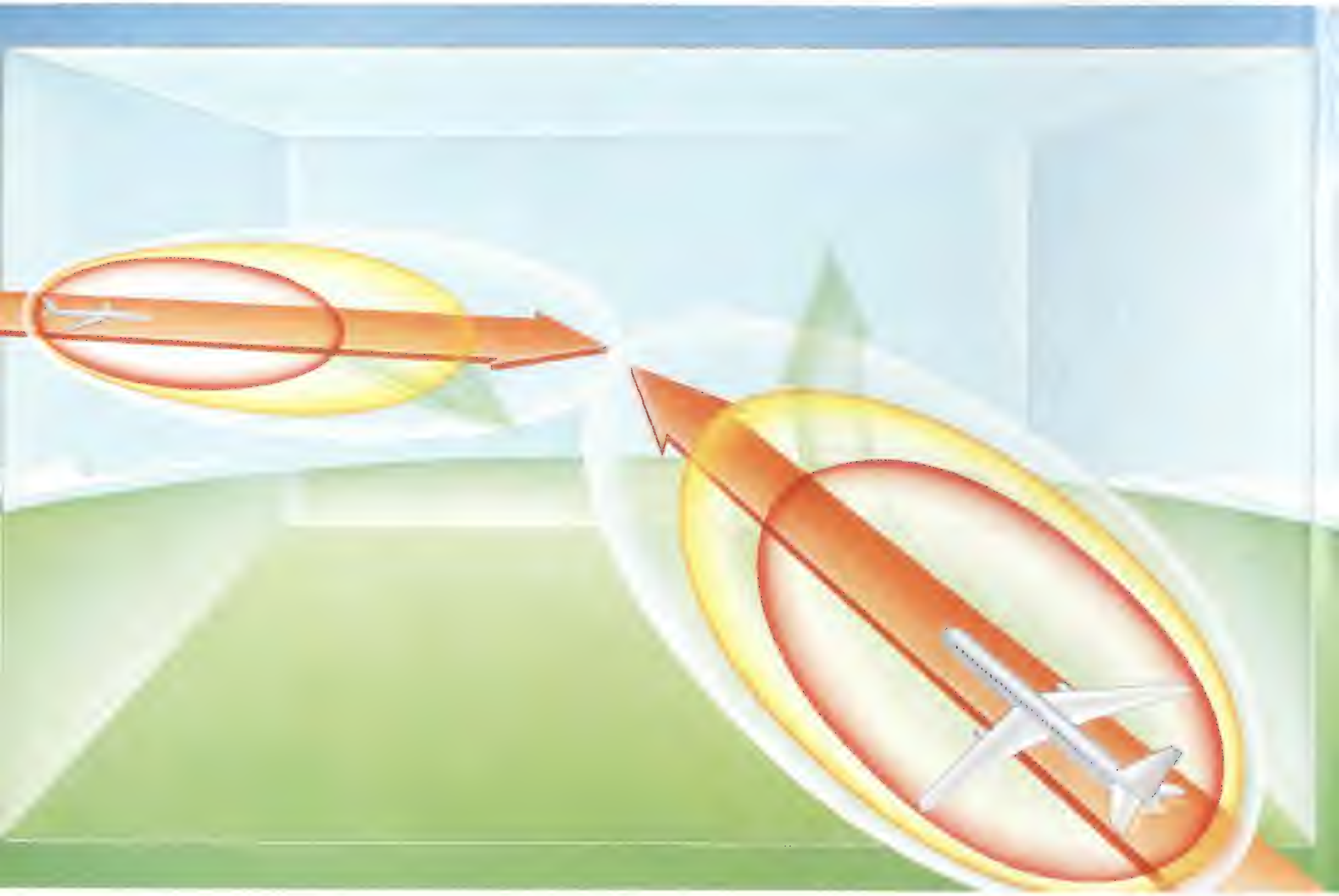
Although the FAA may not have moved as speedily as it could have, there are solid reasons for deliberating long and hard on the architecture of collision avoidance. Would a pilot's maneuver to avoid one collision unravel a controller's careful construct? Where were the lines of authority? When traffic gets dense would unnecessary alarms prove a nuisance? Could an avoidance maneuver create a domino effect, threatening a third aircraft, and then a fourth, and so on?

One crucial point concerned the depiction of aircraft traffic in the cockpit. William Hardaker, an authority on navigation and air traffic control at the Air Transport Association, an organization representing airlines, was closely involved in the long development of collision avoidance (and is now a curatorial volunteer at the National Air and Space Museum's department of aeronautics). "At issue was something called CDTI—cockpit display of traffic information," he says. "There was debate over whether the pilots would see it as a do-it-yourself air traffic control device." At that time the ATA and other groups, particularly air traffic controllers, were worried that once pilots could see other traffic, they'd either ignore the controllers or start wrangling over instructions. The ATA wanted BCAS installed yesterday.

On June 23, 1981, FAA administrator J. Lynn Helms, a retired Marine officer who took on the nation's air transportation system the way Teddy Roosevelt rode horses uphill,

Typically, crews with TCAS II will monitor maximum range at cruise. Should two airplanes require a conflict resolution to avoid a collision, their computers communicate and inform the crews how to maneuver out of the situation.

DALE GLASGOW



announced the decision to adopt TCAS, a system for airliners based on BCAS but with some differences. Calling the announcement a "surprise," the ATA complained that the FAA was moving too hastily with an unproven system and was "not giving sufficient weight to airline views in [its] development work on TCAS . . . ." Dick Bowers, who had been working on BCAS at the FAA until he went to work for the ATA in March 1981, had been at his new job only a few months when Helms announced TCAS. "Nobody was more surprised than I was," Bowers recalls. "It set us back eight years." Today, the ATA acknowledges that it was worth the wait. "The product's good," says Bowers.

TCAS II outlasted Helms, who resigned in 1984, and the system going into airliners today is virtually the one he prescribed. It largely derives from a beacon-based system, but with improvements: it will operate reliably in traffic densities as high as 30 aircraft within five miles, and it is completely independent of ground systems. Some differences are technical: TCAS II adds directional antennas, so that one airplane can interrogate another without tripping transponders all over the sky. And the display of traffic in the cockpit has survived despite the controversy.

In the United States, three companies—Honeywell, Bendix/King, and Collins—are offering TCAS units, and the competition to line up customers has been cutthroat. The chance to sell airlines a required piece of equipment costing around $150,000 to $200,000 comes along only once in a lifetime, and while around 4,000 airplanes have to be equipped, the number of individual airlines making buying decisions is small. One company's representative called the resulting price-cutting a "bloodbath."

The basics of TCAS II are a computer, some form of display in the cockpit, and a transponder. (TCAS I, a simpler system, is being designed for general aviation use and includes only traffic advisories.) The newest generation of transponder operates in Mode Select, or Mode S, which allows the transponder to be addressed individually and enables data to be passed between ground radars and airplanes and airplane-to-airplane, so two airliners can exchange coordination information in order to execute avoidance maneuvers. (Airplanes with older transponders can still be detected and displayed in the cockpit, but they can't participate in resolving a conflict with a coordinated maneuver.)

Once each second, a Mode S transponder emits a "squitter" signal that contains a unique code, or address. A computer on a TCAS-equipped aircraft detects this squitter and issues its own interrogation to the address it just received. With the help of antennas that determine the direction of a signal, the computer determines the relative bearing to the aircraft and, by measuring time intervals, its range. The computer gets the aircraft's altitude by decoding the altitude data portion of the reply.

The TCAS II computer tracks and lists every transponder it detects within a bubble of airspace measuring a minimum of 15 nautical miles (about 17 statute miles) in front and about half that distance to the rear; it also knows its own flight path and altitude. The computer's collision avoidance logic—the heart of the system—can produce a display in the cockpit showing each aircraft it is tracking and can estimate the nearest point at which it will pass. The computer also generates two kinds of advisories: traffic alerts and resolution advisories. Traffic alerts, which merely give bearing and distance information to the pilot, occur when an intruder is about 35 to 45 seconds away. At 20 to 30 seconds' separation, the computer will generate a resolution advisory telling the pilot how to maneuver to avoid collision.

Before that advisory is issued, the two airplanes' TCAS computers must communicate. Each transmits its intent to either climb, dive, or, if already diving or climbing, to hold at a certain vertical speed range. But first each computer checks to see if it has received an intent, in case nearly simultaneous "I intend to climb" (or the digital equivalent) signals ring out from both airplanes. There's even a final arbiter: the airplane with the higher transponder code is programmed to back off and change its intention.

Pilots using TCAS II can get their information through various displays. One, like a miniature radarscope, shows the traffic around the airplane as if viewed from high overhead. Another shows what to do to avoid the collision by indicating a maneuver and a vertical speed—a climb at the rate of 1,500 feet per minute, for example.

With TCAS II, conflicts are resolved only with vertical maneuvers because turning involves banking the aircraft, which affects the orientation of the TCAS antennas and requires additional software. When TCAS III comes, if it ever does, lateral maneuvers will be added. Neither the FAA nor the airline industry claims that TCAS is perfect, but then it's not

COURTESY BENDIX/KING

During the development of TCAS, critics worried that aircrews would use their cockpit displays as a form of do-it-yourself air traffic control.

the primary means for separating air traffic. That remains with the controllers and the ATC system.

Although international carriers flying in U.S. airspace will be required to carry TCAS, outside the United States only the Japanese have required it. The congested airways of Europe would seem to offer the next market, but only Germany seems to be pushing for TCAS, and the International Civil Aviation Organization hasn't extended the requirement worldwide. Many overseas airlines question whether the cost of TCAS is justified. They have a point: according to a National Transportation Safety Board analysis of the years 1977 through 1987, PSA 182 is the only U.S. midair that resulted in a major loss of life, and although airline flight hours and miles flown increase steadily, midairs constitute only a random and infinitesimally small segment of air accidents. And most midairs involve smaller aircraft, not large airliners.

In this country, those arguing in favor of TCAS have taken to using statistics for near-midair incidents—those in which airplanes pass too closely to one another. But the FAA's data comparing 1988 and 1989 show that near-midairs declined 21 percent, from 729 to 573. And FAA officials are quick to point out that near-midair reports may be influenced by a political climate that could encourage pilots or controllers to report incidents, thereby pumping up the numbers and creating a statistical spike that may reflect no real change in the skies.

Although only a few hundred airliners have been equipped to date, TCAS has received good grades. "The pilots I've spoken with have been really pleased with it," says American Airlines spokesman Tim Smith. "We had our first commercial flight in mid-July in a 757 flying from San Antonio to Dallas. It gives you so much early warning you don't have to make abrupt maneuvers."

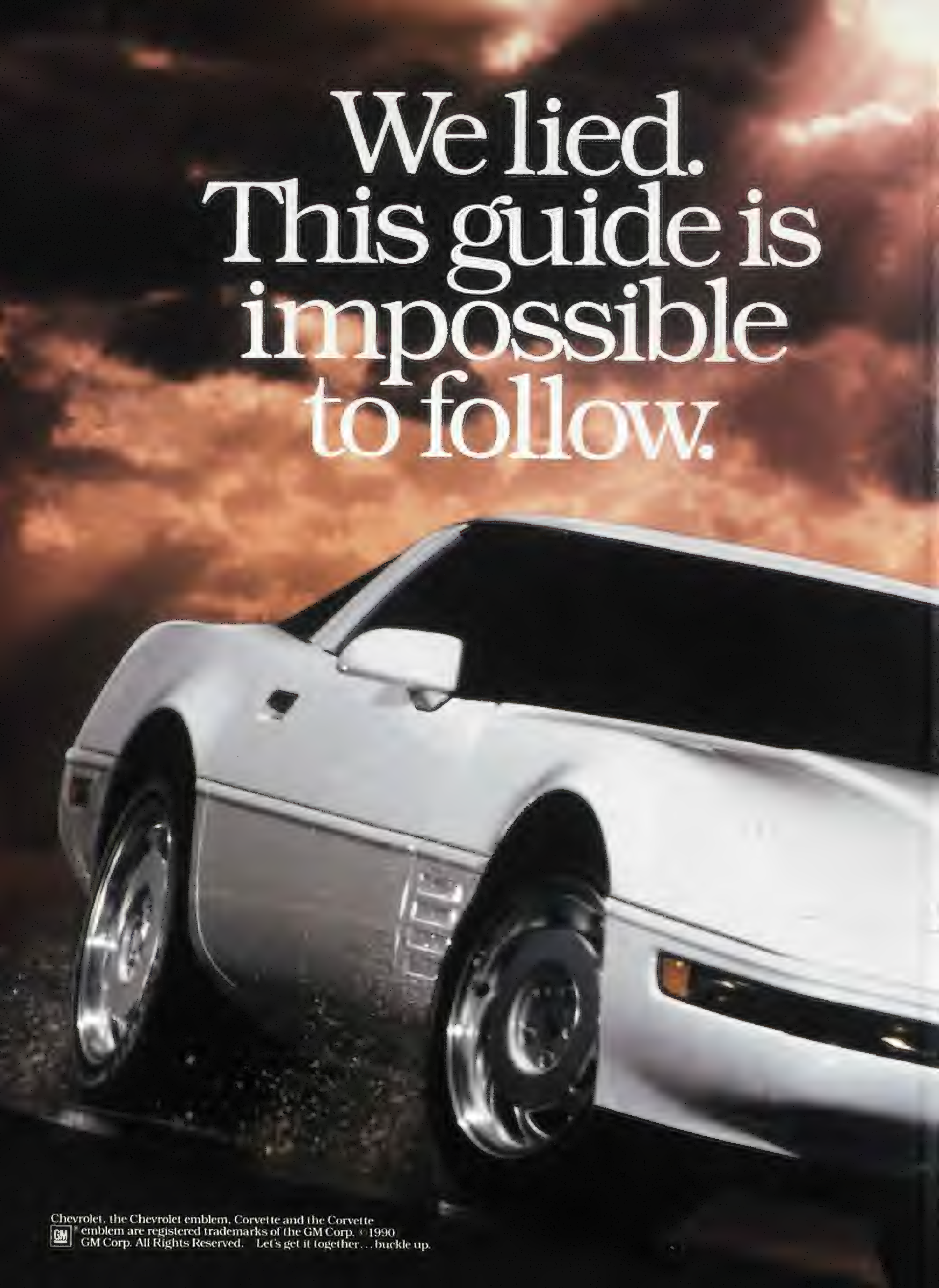
USAir had about 36 units in service by the end of October and was first to obtain TCAS certification. "Crew acceptance so far has been very high," says Norman Bush, USAir's director of flight technical operations. "I've heard nothing but praise for the system, how easy it is to use—it's intuitive. We've already had a couple of resolution advisories issued near terminal areas, and the system worked as advertised with no surprises." The Air Line Pilots Association, a pilots' union, says it's reserving judgment, but it's also pushing hard for the addition of turning avoidance maneuvers—"horizontal resolution," in TCAS jargon—that TCAS III will bring to the party.

If TCAS reduces midairs, we'll probably never hear about it—accidents that don't happen are difficult to count. And it will be hard to prove TCAS made the difference in individual cases. But the most important long-term effect of TCAS may well turn out to be subtle changes in cockpit psychology or the dynamics of the pilot-controller relationship. So far, the airlines are avoiding using TCAS as leverage in arguments with controllers. "We don't encourage pilots to advertise they're TCAS-equipped," says USAir's Bush. "We want the controllers to do their jobs as they always have." Pilots can't help feeling more confident, and air travelers, who are constantly bombarded with assurances of how safe airlines are, have a real reason to feel safer by some increment. The dimensions of that increment, however, will take years to be established.

DALE GLASGOW

On a TCAS II cockpit display, aircraft appear as symbols, with their altitudes presented nearby as two digits representing hundreds of feet. The most distant target appears on the traffic display as an open diamond. When the traffic comes closer, the diamond fills in. Closer still, the diamond becomes a yellow circle, and the computer simulates a human voice saying "Traffic" in the pilot's headphones. When evasive action becomes necessary, the symbol turns to a red square, and the pilot hears a repeated command: "Climb," "Dive," or some variation.


Here's an easy-to-follow guide to the world's leading sports cars.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Corvette ZR-1

The American landscape is littered with a rag-tag collection of pseudo "sports cars" that, over the years, have challenged Corvette's supremacy. We've seen it all. Turbo this. Supercharged that. All-wheel drive. Front-wheel drive. Even port holes. But in the end, after the hype is long gone, they all find out the hard way. You don't take on 38 years of experience in building America's only true sports car unless you can match our seriousness of purpose, our relentless dedication and our flat-out will to win.

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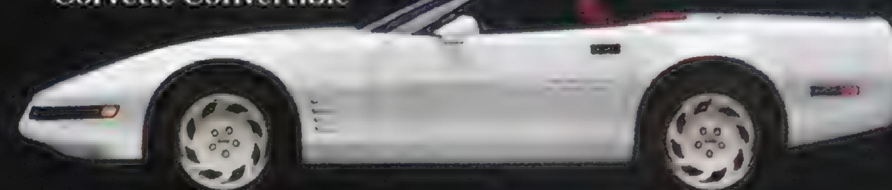
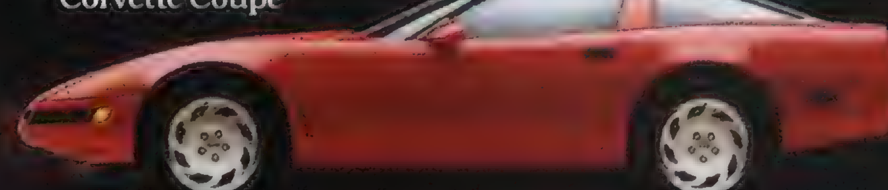
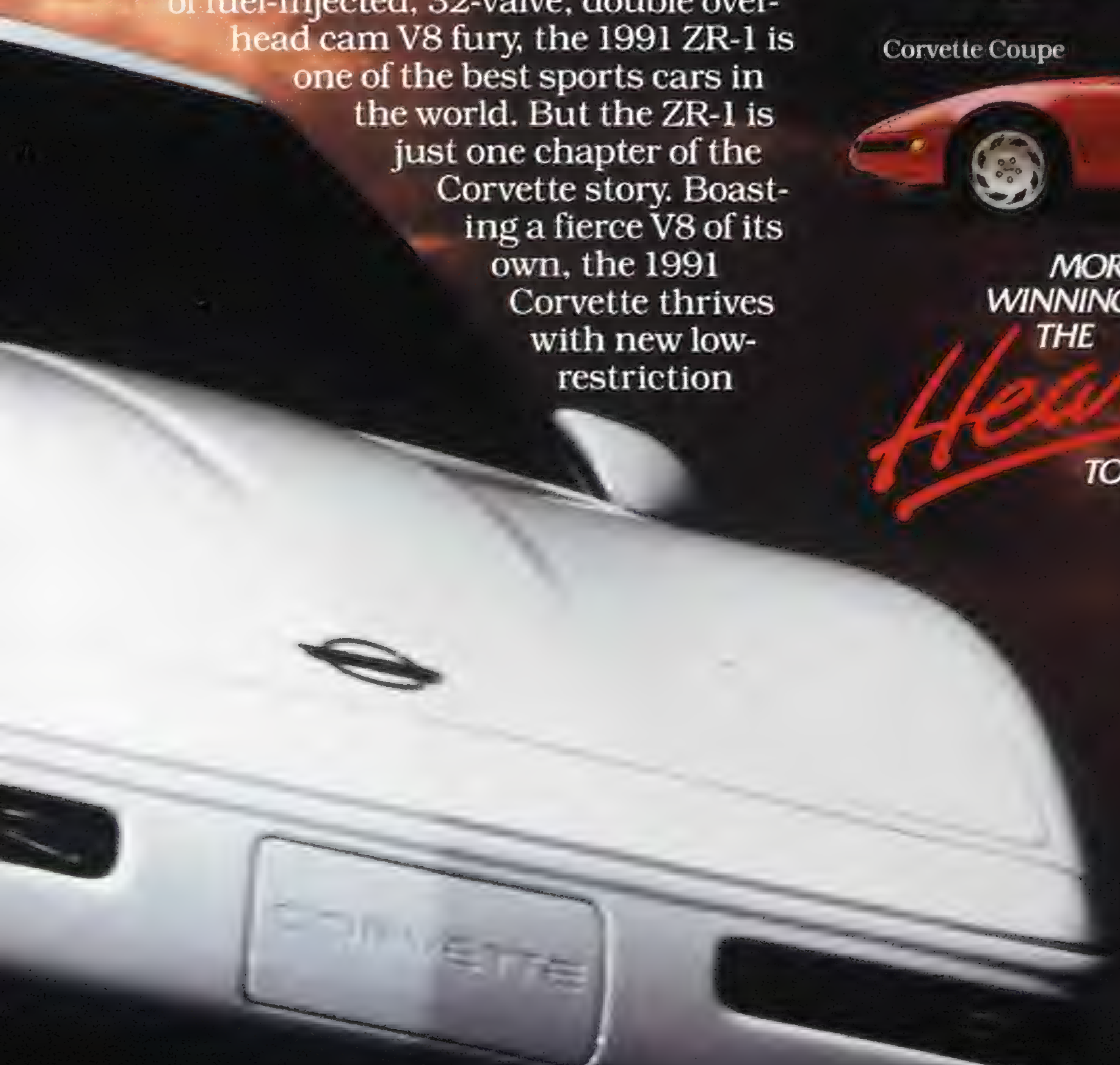
Corvette Convertible



Corvette Coupe





MORE PEOPLE ARE WINNING WITH THE *Heartbeat* OF AMERICA

TODAY'S CHEVROLET™

by Stephan Wilkinson

At the speed of sound, air fights back.

Assaulting the Barrier MACH 1

Ralph Virden was the first to fall. Virden, a Lockheed test pilot, was flying his P-38 through a dive test in November 1941 when the airplane pitched manically and became nearly uncontrollable because of what later came to be called "Mach tuck." The twin-engine Lightning, gaining speed in the dive, was still well below the speed of sound, but the air accelerating over its wing was moving faster than the airplane itself. When Virden hit Mach .675, the airflow over the wings became supersonic. A shock wave leapt to life over the wing stubs between the fighter's lozenge-like cockpit cab and its engine nacelles. The inboard wings suddenly stalled; the airplane slumped. The usually strong airstream that the wings guided back and down onto the fighter's horizontal tail ceased, no longer counterbalancing the weight of the engines and forward structure. The nose rotated down—"tucked."

This wouldn't have come as a surprise to Virden. P-38 designer Kelly Johnson had been one of the first to postulate the effects of compressibility, the baffling behavior of air moving at supersonic speeds. So the P-38 that Virden was flying, one of the first of the twin-boom fighters to be built, had a raised tail, which had already been fitted with special devices to give it more muscle in the inevitable struggle to regain balanced flight.

What Johnson and Virden didn't know, because Lockheed's wind tunnel couldn't simulate speeds as high as its P-38 could reach, were the exact locations and various strengths of the pressures working on the aircraft. So when Virden activated the spring-loaded servo tabs on the elevator, he thought they would help him wrench the tail back down. They worked too well: the forces of the dive recovery pulled the airplane's tail off, and Virden died in the ensuing crash.

The supersonic era truly had begun for the United States. Flying faster than sound had moved from theory and wind tunnels to real airplanes carrying real pilots and acting in ways nobody yet understood. In less than 20 years, airplanes had progressed from speeds that can be surpassed today by most Toyotas to velocities at which 2,000-horsepower metal monoplanes could knock on a door that even now isn't fully open.

U.S. aviation came late to high-speed flight. The Germans were experimenting with quadrupling and quintupling airspeeds in 1922 at Göttingen, while the Jenny was still the hot setup for U.S. pilots. Fritz Opel flew the first rocketplane in 1929, and in 1935 Europeans organized an entire scientific congress devoted to supersonic flight. They met in Italy, whose air force had already established the world's only high-speed-flight research squadron. Three years later a high-level study by the U.S. Navy stopped research on jet propulsion, concluding that gas-turbine engines would forever be too big to power anything smaller than ships.

Still, U.S. pilots couldn't help nibbling at big-time Mach percentages, for even their piston-engine

One of the fastest World War II fighters, the Lockheed P-38 was the first victim of compressibility.

LOCKHEED

BRITISH AEROSPACE (2)

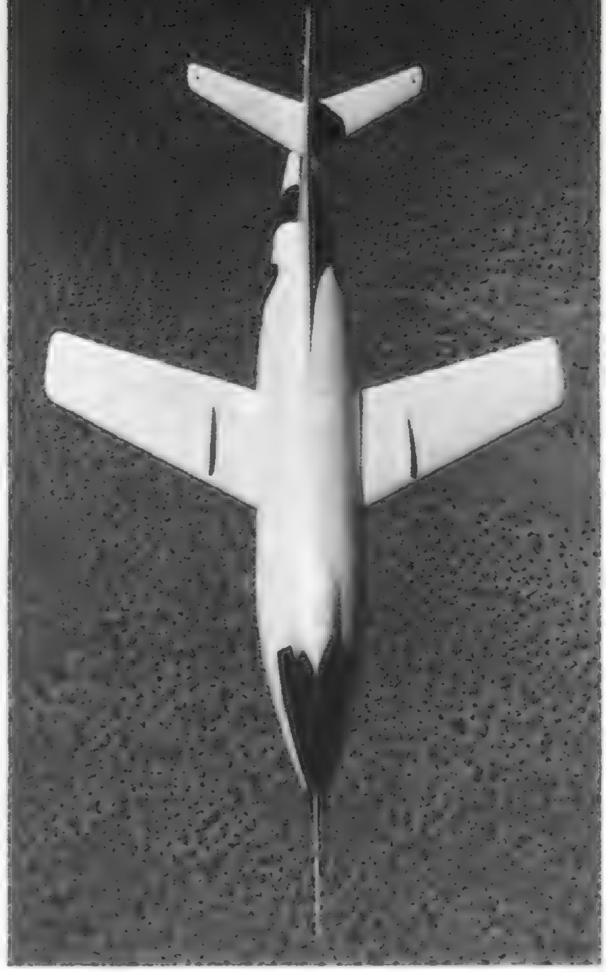
Standing shock waves spring up wickedly where the airflow reaches Mach 1, whether the air is blasted past a model in a wind tunnel or shoved aside by the British Lightning in flight (right).

airplanes had become so sleek and heavy that gravity could pull them to speeds where they butted up against the phenomenon called compressibility. "We knew about Mach 1 going clear back to the P-36 and the P-40," said the late Herbert O. Fisher, the former chief production test pilot of the Curtiss-Wright Corporation, which manufactured those early Hawk fighters—the retractable-gear successors to the big biplanes. "Nothing could go 600 mph in level flight, but pilots were beginning to dive fighters. We ran into compressibility back in '38."

The mystery of compressibility had already created one of those says-it-all catch phrases—like "cold fusion" and "computer virus"—that reporters love because it characterizes something that they lack either the space or the understanding to explain. Not many people remember W.F. Hilton, a British aerodynamicist, or the reporter who in 1935 asked him about the purpose of the National Physical Laboratory's new high-speed wind tunnel. Everybody remembers what Hilton said, though. He displayed a graph plotting the abrupt increase in airfoil drag as its speed nears Mach 1. "See how the resistance of a wing shoots up like a barrier against higher speed as we approach the speed of sound?" he explained. Barrier ... speed ... sound ... Sound Barrier!

The imagery took hold. Twenty years later, Douglas D-558 test pilot William Bridgeman described flying on "the reef of the sound barrier, where compressibility lurked to shake a plane to pieces or suck it out of control straight down into a hole in the ground. As a result of combat demands, aircraft had to be flown right into this monster."

To those unfamiliar with the science behind the buzzword, "sound barrier" may have the same effect as "time warp," conjuring up some kind of boundary between safe, understood reality and a mystical zone of perverse forces. Hilton brought up the subject of sound for a very good reason, however, because of the way molecules of air respond to a disturbance in their midst. A molecule at the point of disturbance, which could be an airplane beginning to move, a lightning bolt rending the air, or a human voice, bumps into the next molecule, and that molecule into the next,



NASM

The Douglas D-558-2 Skyrocket pushed past Mach 2 on November 20, 1953, beating an advanced X-1 to the record.

and so on, like a line of falling dominos. This is exactly how sound is transmitted. Excite those air molecules too fast, however, and the molecules don't just nudge the next ones on, they bunch up like commuters in a Tokyo subway. They *compress* and form a shock wave (see "Piling On," opposite page).

"The pressure of an oncoming aircraft is transmitted to the air," explains Howard Wolko, special advisor for technology at the National Air and Space Museum. "As the airplane goes faster and faster, it gives a shorter and shorter signal, and the air can't prepare itself. And when that happens, Bernoulli's Principle goes to hell in a handbasket."

It's not that the air forms a wall of any sort—a "sound barrier"—though it is indeed compressed to a greater density than the ambient atmosphere. The problem is that the shock wave that develops at some point on the airframe, almost invariably first atop the wing, acts like a spoiler, ruining the airflow and therefore the lift. But "Breaking the Lift Spoiler" would never sing as a movie title.

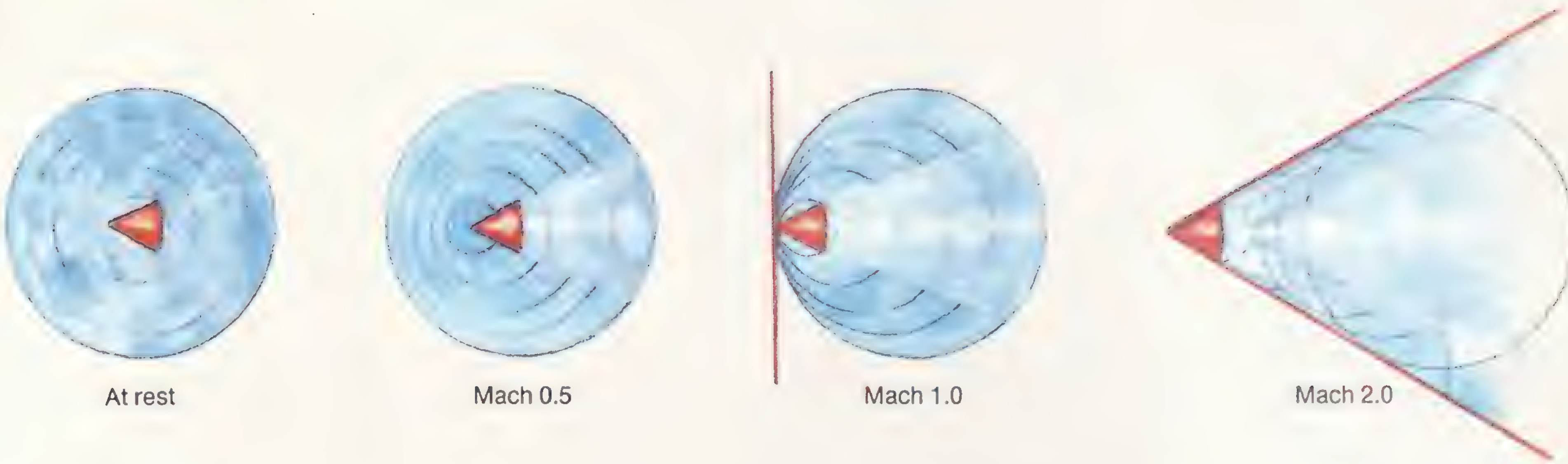
"There never was a sound barrier, and I don't think any serious engineer ever thought there was," muses Wolko, who was on the engineering team of the supersonic Bell X-2 project. But as Kelly Johnson learned when he lost his test pilot, engineers had come up against some kind of barrier: a control barrier or a knowledge barrier or, as one engineer described it, "a wind tunnel techniques barrier." As the frenzy of production to meet combat demands intensified in the early 1940s, one high-performance aircraft after another found the invisible enemy that killed Ralph Virden. Early models of the Republic P-47 Thunderbolt, the Curtiss SB2C Helldiver, and the Bell P-39 Airacobra all broke apart in dives.

"You can imagine their frustration," says aerospace historian Richard Hallion, who has written several books about the U.S. engineers and pilots who pushed into supersonic flight. "Their best airplanes were falling out of the sky, and they didn't have wind tunnels that could give them accurate data at the speeds where the airplanes were running into trouble. They had just solved the propulsion problems; they could see jet engines on the horizon. And now here was another altogether different obstacle they had to overcome. And they didn't have the research tools to do it."

After Ralph Virden crashed, Kelly Johnson, desperate to find a cure for the P-38's woes, sent a model to the National Advisory Committee for Aeronautics for wind tunnel tests. The NACA suggested an elegant solution to the problem, an all-moving, trimmable horizontal stabilizer, one of the design features that allowed the Bell X-1 to maintain control as Chuck Yeager flew it "through the sound barrier" on October 14, 1947. But in the middle of a war, with almost 700 of the fighters on order, the company couldn't afford the time for the redesign.

Instead, the NACA developed small, wedge-shaped "dive flaps" that were popped out of the underside of the wing at the first sign of Mach tuck. Many to this day assume the dive flaps simply slowed the airplane below shock wave speed, but the truth is that they restored enough of the wing's lost lift to enable the pilot to pull out despite the tail's recalcitrance. They worked well enough to also be installed on some of the P-38's contemporaries: P-47 fighters, A-26 attack bombers, and the two earliest U.S. jets, the P-59 and P-80.

Fixes like these merely delayed the control problems past Mach .675 into



At rest Mach 0.5 Mach 1.0 Mach 2.0

Piling On

If you've ever seen the circles rippling outward from a pebble tossed into a pond, you can imagine the invisible disturbance waves that radiate in three dimensions from an airplane—or any other disturbance—in the atmosphere. Disturbance or pressure waves are the very phenomena that transmit sound; the speed at which they pulse outward, therefore, is also the speed at which sound travels.

An airplane moving slower than the speed of sound stays comfortably behind the forward-moving wave fronts, which perform a certain service for the airplane by preparing the air for its arrival. At this speed the airplane politely bumps aside the air molecules in its path. Each molecule has time to move out of the way and to nudge its neighbor out of the way as well. Pick up the pace, however, and the wing (and/or the tail, cockpit canopy, radome, or any other airframe component) of an airplane flying close to or faster than the speed of sound arrives before the air knows it's coming.

As an airplane increases speed, the wave fronts ahead of it get closer and closer together. When the airplane reaches Mach 1, the wavefronts overtake one another and pile up in a concentrated front, a "shock wave." A shock wave marks an instantaneous change in air pressure, temperature, and density.

Past Mach 1, the combined motions of the airplane and the pressure waves still radiating outward form a conical front, which moves continuously with the airplane and which engineers call a "Mach cone."

WEB BRYANT

Subsonic airflow

Supersonic shock formation

Transonic Trouble

Before the Mach cone forms, when the airplane itself is traveling at about Mach .7, the faster moving air over the airplane's wing can reach Mach 1. At that point, shock waves form on the wing, destroying its lift and creating drag, as well as interfering with the work of control surfaces.

At slower speeds, when all is going as planned, a wing creates lift by making the air above it accelerate. Because the air moving over the curved upper surface of the wing has a longer distance to travel, it must move faster to reach the back of the wing than the air flowing along the straight underside. The faster-moving air has a lower pressure than the slower air. Depending on whether you look upon your glass of scotch as half full or half empty, the wing is either being pushed up by the positive pressure below or sucked up by the negative pressure above.

The air is at its fastest usually about one-third of the way aft on the wing, where it has just accelerated over the curve at the leading edge. As soon as this airflow reaches Mach 1, a shock wave forms. The shock wave slows the air as handily as a spoiler would if it were raised up in the air's path. When the air slows, its pressure increases and the wing's lift drops. Matters quickly go from bad to worse. At the same time the air slows down, its temperature increases, because, according to the law of conservation, the amount of energy in a system remains constant, though its form can change. The propulsive energy that had been used to produce speed is now wasted in producing heat instead. This is a literal drag. The drag becomes even greater because the shock wave has also caused the airflow to separate from the wing. If the airplane has enough power to overcome the drag, it can push through the troublesome formation of shock waves to supersonic speed. If not, its speed is limited by the drag it encounters at this point.


FU-131

the troublesome speed band on either side of Mach 1, from about .8 to 1.2, a region that engineers call "transonic." (NACA director Hugh Dryden and Theodore von Kármán of the California Institute of Technology coined the term. Dryden wanted to spell it "transsonic," which, strictly speaking, is correct—"across the speed of sound." Von Kármán, who presumably would also have voted for crossection over cross section, prevailed.) Transonic denotes the range of speeds between formation of the first shock wave and the speed at which the entire wing has "gone supersonic" and is no longer encountering a troublesome mix of subsonic and supersonic airflow. At this point, an airplane has not only passed Mach 1 but also achieved stable, trimmed, controlled flight faster than sound.

Early experiments in transonic flight were dicey, intuitive affairs. In one experiment, for example, the NACA arranged to have a propeller-less P-51 towed aloft like a glider by a big twin-engine Northrop P-61 night fighter. The engineers were trying to get real-world figures exactly comparable to P-51 high-speed wind tunnel data in order to assess how accurate the wind tunnel was, so they needed to eliminate such factors as prop and even exhaust thrust.

Unfortunately, on one early flight in California the double-cable tow tether—like the pull rope on a child's sled—came adrift from the P-61 before the Mustang could cast itself loose and begin the glide back to what was eventually to become Edwards Air Force Base. The metal lines snapped back and wrapped themselves firmly around the Mustang, quite complicating the already-necessary deadstick landing. Jimmy Nissen, the NACA pilot, bellied the P-51 in on the Muroc dry lakebed, but the flailing cables took out all of the base's powerlines in the process. It was fortunate that Nissen didn't break anything during the rough landing, for when he got to the hospital there was no current to run the X-ray machine.

The P-51 was of special interest to the pioneers of supersonics because among fast World War II fighters, the Mustang seemed the most resistant to high-speed controllability problems. Apparently its unique laminar-flow airfoil managed to keep the airflow attached despite shock wave-induced perturbations. The P-51 could dive faster, under control, than any other World War II fighter. In 1946 and '47, Chuck Yeager in a P-51D with full instrumentation and cohort Bob Hoover in a P-47 dove "straight down, wide open, from as high as we could go," Yeager later wrote to a friend. Yeager reached Mach .81 in the Mustang and Hoover managed .805 in the bluff, radial engine Thunderbolt.

So it was a P-51 pilot—NACA engineering test pilot George Cooper—who first manipulated supersonic shock waves in flight. Cooper discovered real-world evidence of the wind tunnel phenomenon called the Schlieren effect, created when light is refracted by the denser shock wave air. The phenomenon is visible either under controlled wind tunnel lighting or when the angle of sun and wing are just right. Cooper, fascinated, was able to make the shock wave move aft as he increased dive speed, move forward as he positioned the aircraft to increase lift, and dance back and forth—or "buzz"—at a specific Mach-versus-lift value. (His NACA test Mustang was amply equipped with instruments.) The buzzing coincided with control buffet, for at that speed the unstable shock wave was disturbing airflow over the P-51's control surfaces.

Even more fascinated was NACA engineer Robert Gilruth, who realized that some of the local airflow over the wing of Cooper's Mustang was going nicely, controllably, predictably supersonic. The NACA had been trying to do transonic research by dragging high-speed models to extreme altitudes aboard a B-29 and an F-82 Twin Mustang and then dropping them straight down onto a bombing range near Langley, Virginia—getting brief bits of data by

What's Ackeret 1?

Ernst Mach, the man whose name has become synonymous with high-speed flight, never saw an airplane that traveled much more than one-tenth the speed of sound, for he died in 1916. Mach published the work that resulted in the concept of "Mach number" in 1887, 15 years before the airplane was even invented. He hadn't the slightest interest in aircraft and was actually studying the flight of artillery rounds when he did his pioneering work on quantifying the speed of sound—and was doing it largely as an outgrowth of some photographic laboratory techniques he had developed to study sound wave propagation from meteorites, explosions, and projectiles.

How odd that two of the most significant technological achievements of our lifetimes both devolved in part from the arcane science of ballistics: not only Mach's work on supersonics but the development of computers in the 1940s to create precise artillery firing charts for gun-laying.

Nonetheless, Mach wouldn't be pleased that he's universally remembered as a result of that virtually inconsequential experimental dalliance rather than for his work as a psychophysiologist, his criticism of classical physics and mechanics, or his contributions to Einstein's theory of general relativity. Who remembers Mach's band? (Not a ragtime group but a phenomenon that relates the physiological effect of spatially distributed light stimuli to visual perception.) Anybody you know been quoting the Mach principle? (Einstein's term for Mach's claim that the inertia of an isolated body can have no meaning.) Who gets any crossword puzzle mileage out of Mach angle? (The actual object of his supersonics research—the angle between a shock wave and the direction of motion of the object creating the wave.)

No, it's "Mach number" that will go down through the ages as the legacy of this stubborn, brilliant, and multi-talented Czech scientist-philosopher.

But don't feel sorry for him. Save your laments for Jacob Ackeret. Remember him? He was the director of the Institute of Aerodynamics at the Swiss Federal Institute of Technology, and in 1929 he suggested the term "Mach number" for the ratio of the speed of an object to the speed of sound in the medium within which the object is traveling. If he'd had a good PR guy, we might today be quoting Ackeret numbers, discussing Ackeret-2 Concordes and determining critical Ackeret.

North American took a chance on swept wings in 1945 and hit the supersonic jackpot with its F-86 Sabre.

tracking the plunging models with radar or by laboriously digging them out of the mud and reading the instrument recordings that had survived.

Putting a tiny model atop a strut or "sting" on a P-51's wing, right in the airflow that in places had accelerated to speeds of Mach 1.4, seemed much neater. From this experience, engineers realized they could reproduce the same effect right in their transonic wind tunnels by mounting models atop wing-shaped "bumps," where they would also encounter supersonic air.

When the U.S. Army Air Forces imported Frank Whittle's jet engine from England in 1942, the Jet Age did not arrive with it. The Bell P-59, the Air Force's first operational jet fighter, was still too slow to get itself in trouble. The next jet, the Lockheed P-80, was fast enough to suffer from aileron buzz caused by the capricious dance of shock waves on its control surfaces. But again the problem was encountered only in steep dives and again was counteracted by fortifying the control surfaces.

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Infamous for the crash that killed British test pilot Geoffrey de Havilland in 1946, the tailless D.H. 108 Swallow exceeded Mach 1 two years later. The British abandoned tailless designs for delta and highly swept wings, like those of the Lightning (opposite).

Not until after World War II did aircraft design take the radical turn toward supersonic flight that the jet invited, producing airplanes that looked strikingly different from their subsonic forebears. The changes derived mainly from two sources of information: NACA high-speed flight research and the scientific war spoils from Germany. The first easy answer to going faster, which turned out to be swept wings, came from both.

The NACA's Robert Jones had been quietly studying the effect of sweepback on the lift of large-span wings at the research lab in Langley, Virginia. He completed a formal report in April 1945, which the NACA issued on June 21 to the military services and companies with security clearances. That May, Boeing engineer George Schairer accompanied von Kármán, then the Army Air Forces' chief scientist, on an intelligence gathering mission to a once-secret aeronautics research installation in Braunschweig, Germany.

Poking into various offices in the laboratory, Schairer and von Kármán came upon a small model of an airplane with

The Sonic Boom

They don't call them "booms" for nothing. If you're imagining rolling thunder, think instead of a cherry bomb in a trash can. Given the right combination of atmospheric conditions, altitude, and airplane—particularly its weight, shape, and maneuvering configuration—the sudden arrival of a shock wave can sound like trains colliding. Oddly enough, one parameter that matters little is speed: above a certain Mach number, a sonic boom can actually weaken as the airplane goes faster.

The first human-made sonic booms (supersonic bullets and artillery shells aren't heavy enough to create the phenomenon) were trailed by German V-2 rockets reentering the atmosphere, rattling English windows far below as the missiles headed London-ward to do far worse.

In 1949 sonic booms were still rare enough that the San Francisco sheriff's department dashed about trying to find the source of mysterious "explosions" reported by worried suburban residents. Turns out that the NACA's nearby Ames Laboratory had just acquired an early F-86 Sabrejet, the first production aircraft that could go supersonic, and two NACA test pilots were routinely doing just that.

The British soon discovered that sonic booms were so spectacular you could build entire airshow routines around them. The Brits had experimented with using booms as weapons, maneuvering an aircraft to "throw" the thunder at structures. Concluding that breaking the enemy's dishes really wouldn't change the course of battle, Royal Air Force pilots nonetheless perfected the technique of pitching the sound at the crowd during the then annual Farnborough Show, and it got so the size of your boom was a greater measure of pilothood than wristwatch complexity.

This all came to a tragic end in September 1952, when de Havilland test pilot John Derry pulled apart a D.H. 110—the prototype Sea Vixen—trying to make a yet-bigger boom. One of the 110's two engines somersaulted lazily into the Farnborough crowd, killing 28 and injuring 63, forever making anathema at Farnborough, and throughout the United States as well, the act of flying directly toward an airshow crowd.

Air Force pilots boomed for the fun of it during the '50s. "We used to hear sonic booms all the time when I was teaching at Texas A&M," reminisces Howard Wolko, a curator at the National Air and Space Museum. "Whenever a graduate joined the Air Force and finished training, he'd come back and buzz the campus supersonically. You'd hear it and just think, *Oh, yeah, another Aggie got his wings.*"

That tradition ended when one fighter jock centerpunched his own field with a particularly powerful shock wave created by a dive to 8,000 feet. He broke windows, loosened doorframes, and cracked ceilings all over the base, ending the era of casual sound-barrier breaking, although isolated incidents continued to cause damage and injuries.

Strain gauges installed in houses that have been subjected to sonic booms show that the increase in pressure distorts a small building by a fraction of an inch. Two shock waves travel with an airplane flying faster than sound, one at the nose and one at the tail. The passage of the first almost instantly raises the air pressure slightly. In the 0.3 second or so before the second shock, the pressure rebounds to slightly less than ambient. The arrival of the second shock restabilizes it. This double whammy not only breaks windows but creates that characteristic *boom-boom* of a low-altitude supersonic flight.

The intensity of sonic booms is measured by the increase of pressure, or "overpressure," and it can be doubled and

swept wings. Both had been closely following Jones' studies and were anxious to get their hands on anything relating to the design of the model, but the sullen German aerodynamicists in Braunschweig shrugged off their questions. Von Kármán decided to play good cop/bad cop. Though the Soviets were nowhere nearby, he turned to his assistant and loudly said, "We're through here. I think now it's time to notify Russian intelligence to take over." Terrified by the thought of a Soviet debriefing, the German director of engineering took von Kármán's assistant to a nearby drywell and showed him where they had dumped all their best research, including considerable wind tunnel data on the behavior of swept-back wings in the transonic regime.

Schairer immediately wrote Boeing headquarters, telling the company to stop work on a straight-wing dodo of a Mach 1 design that was already well under way. He returned to Seattle with microfilmed German data that resulted in the Boeing B-47, progenitor of the 707 and the B-52. The NACA's equiva-

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tripled by maneuvers such as pull-ups and steep banks. Since the shock wave trails from the airplane at an angle, it's thought that the ultimate sonic booms are produced by dives just steep enough to cause the entire "face" of the shock wave to arrive on the ground at once.

The all-time Glass-Makers' Appreciation Award, however, should go to the U.S. Air Force F-104 pilot who in November 1959 buzzed an uncompleted terminal at Ottawa's Uplands Airport at 500 feet and did $300,000 worth of damage to windows and the roof.

Little more was known about sonic booms until the mid-1960s, when the Federal Aviation Administration, assigned to determine the social acceptability of supersonic transports, did what it claimed was more research on noise than had been done in the whole of human history.

During 1964 the FAA had the Air Force wallop Oklahoma City with eight sonic booms every flyable day for six months, using the area's 700,000-odd inhabitants as unwitting and unwilling subjects in an experiment to determine society's threshold of auditory pain. Century-series fighters and B-58 Hustlers played the city like a drum, which doubtless is why the project was code-named Operation Bongo.

The effects of the booms ranged from the inevitable to the incredible. One victim claimed that her bra strap snapped whenever the Air Force lowered a particularly loud boom. ("The engineers had a strain gauge all fixed up for her, but she wouldn't give her name," said one FAA spokesman.) Another Sooner said the daily 7:00 a.m. blast scooted her bed across the floor. A third claimed her furniture was shrinking. But some effects were serious. A high school student was beaned by a light fixture jogged loose during history class. An Oklahoman with hypertension was ordered by his doctor to leave the city for the duration of the tests, for the sound of the booms made him so furious that he quite literally could have died.

In all, the FAA got 15,116 complaints during the Oke City tests, sometimes as many as 500 a day. Many of them were simple noise gripes, but legitimate suits for property damage ended up costing the government $123,070 in the five years following the experiment.

Dismayed by the negativity of the Oklahomans and curious about how much of the claimed damage was boom-caused, the FAA built a small mock village on the White Sands Missile Range in New Mexico and bombarded it in January 1965 with F-104 thunderclaps producing as much as 10 pounds of overpressure per square foot—far more than the Oklahoma test's levels.

Nothing broke, so the FAA proudly called in the press and did the demo for the TV cameras. Asked to make one more pass ("and get it real low so we can get a good shot . . . "), the Starfighter pilot got carried away: his 39-pounds-per-square-foot blast turned the town into what could have passed as the set for a spaghetti-Western barfight, with broken glass everywhere. All the FAA could salvage from the PR shambles was the claim that 2,000 chickens hatched from eggs that had been subjected to sonic booms had a higher fertility rate than those developed in reverent silence.

In 1965 the Air Force made a series of supersonic mock attacks on Chicago with B-58 Hustlers. Among other damages, the entire plaster ceiling of a large conference room in an Evanston church collapsed during one run, and during another a 14-year-old boy took an 11-stitch cut from an exploding pane of glass in his high school classroom. Though sonic booms were sometimes referred to in those days as "the sound of freedom," 2,520 unimpressed Chicagoans filed damage claims and were paid over $65,000, just over $1,000 per bombing run.

Mach 1 With a Propeller?

"There I was at 40,000 feet," the young Army Air Forces pilot begins—really—"in the AAF's latest P-47N with a very specific purpose in mind, mischievous as it was."

Lieutenant Raymond Hurtienne's purpose, it turns out, was to break the speed of sound in a propeller-driven aircraft, and he swears he did it, in the spring of 1945, in the skies above Long Island. "I rolled her over, pointed her straight down, retarded throttle, full left trim and full forward stick," he wrote in a letter to a P-47 pilots' association. "As the speed increased, control responses became more and more rigid. The airspeed indicator became stuck against the peg at 575 mph. Vapor trails were forming at both wingtips. The stick seemed like concrete. The altimeter was unwinding at a terrific rate. This was it: I had hit Mach 1. There wasn't another plane in the skies that could touch me."

That sort of thing seriously griped Herbert O. Fisher, and mischief had nothing to do with it. Herb Fisher, who died last July at the age of 81, made a living diving Republic P-47 Thunderbolts to their absolute maximum controllable airspeed while he was a test pilot for Curtiss-Wright's propeller division after World War II. He would have been the first to tell you that neither he nor anyone else ever put a World War II piston engine aircraft through the sound barrier. Or, as fellow test pilot Tony Levier once put it, "Anyone who did ain't here to tell about it."

Fisher wore the high-belted pants and tucked-in tie of a man in his 80s, but his eyes were clear, his voice strong, and he had an easy laugh. He chuckled about the radar detector in his big station wagon (New Jersey plates P40P47, for the two airplanes that were his specialty), saying he *never* drove faster than 60 anyway. But once he routinely did 10 times that speed in a P-47—an airplane built for a real-world maximum of a little over 400 mph. Fisher made over 100 high-speed descents from altitudes as high as 38,000 feet and achieved instrument-verified airspeeds of Mach .83 (about 600 mph at that altitude)—but no higher.

"The first time I heard this sort of thing was an Air Force pilot who came out with publicity that he went Mach 1 in a Thunderbolt over Europe," Fisher groaned. "There's no *way* he could have gone Mach 1, but he still believes it. He's still out there preaching it."

Other U.S. and British pilots have claimed to have done it as well, recalling flights in Spitfires, P-38s, P-47s, and P-51s. But there is one basic, irrefutable reason why their claims are, as Fisher might have put it, malarkey. A propeller—even one designed to current state-of-the-art standards for maximum efficiency—continues to create thrust up to a point somewhere short of supersonic. At that instant, it suddenly loses efficiency and begins to create not thrust but enormous drag. "It becomes a flat plate," Fisher said; "a big *brake.*" One Spitfire pilot, who attained the highest verified speed, Mach .9, achieved by a World War II propeller-driven aircraft, discovered this in a big way when the sudden braking forces became so powerful during a dive that the entire propeller and most of the engine cowling broke off.

So the only conceivable way a propeller-driven airplane could go supersonic might be with the prop stopped and feathered, in a terminal-velocity dive. But even that wouldn't have worked in the 1940s, since airframe design was still taking baby steps through the transonic range. Immediately after World War II, Kelly Johnson, the legendary Lockheed Skunkworks engineer, built a six-foot-wingspan, 600-pound, solid-steel model of the Lockheed P-80A Shooting Star (later designated F-80) and had it dropped from a P-38 at altitudes close to 40,000 feet. "In a vertical dive," he wrote in a letter to Fisher, "the model would not exceed a true airspeed of higher than Mach .94. With the full-scale model of the Lockheed F-80A, these results were confirmed, and there was no recorded case where this jet fighter, clean as it was, could ever exceed Mach .9."

Herb Fisher was a great fan of the P-47, but he also recognized its limitations.

COURTESY H. FISHER JR.

Leonard Greene, an engineer, ex-Grumman test pilot, and aviation entrepreneur who once developed important theories of high-speed aerodynamics at the Institute for Advanced Study in New Jersey, rolls his eyes and looks even wearier than usual when the possibility of World War II-type aircraft exceeding Mach 1 is broached. "We don't have enough thrust *today* to put onto any World War II aircraft and make it fly at supersonic speeds," he says. "Besides, it would come apart first."

So were the P-47 pilots fibbing? Not at all, Fisher (and Johnson) explained. They were tricked by a simple phenomenon: airspeed indicators don't function reliably in high-speed dives. The airplanes are falling so fast they can't measure static air pressure quickly enough: while the instruments were down *here,* they were still measuring air from up *there.* Had neophyte Hurtienne's indicator been accurate at an indicated 575 mph at 20,000 feet, for example, his true airspeed would indeed have been at least Mach 1.05 at typical temperatures. But it wasn't. Because the airspeed calculation would have been based on an artificially high altitude reading, the airspeed indicator would show the airplane to be traveling faster than it really was.

Still, there are records to be set in flirting with Ernst Mach's big One-Point-Oh in a Thunderbolt, and Herb Fisher helped set one few would dare try to top. Some 40 years ago—during an era that obviously predated corporate legal departments, liability suits, OSHA rules, and subparts of parts of Federal Aviation Regulations—Herb Fisher sat his three-year-old son on his lap, clamped an oxygen mask to the child's tiny face, climbed to 30,000 feet, two-blocked the throttle, pushed over, and took Mrs. Fisher's boy along on one of his Mach .8 dive tests, making Herbert Fisher Jr. "the fastest baby in the world."

LOCKHEED

The short, thin wings of the F-104 made landings tricky even for its test pilot Tony Levier.

lent data from Jones' report convinced North American to put swept wings on a somewhat refined Air Force version of the FJ-1 Fury—a slow, tubby, straight-wing Navy jet that had already gone into limited production. The result was the F-86 Sabre, the first operational fighter in the world routinely capable of flying faster than sound (though it took a slight dive to do it) and one of the most aesthetically pleasing and operationally successful aircraft ever built.

Why the Bell X-1 challenged the "sound barrier" with straight wings when those of airplanes all around it, including its sibling rival, the Douglas D-558-2 Skyrocket, were swept has been a matter for interpretation since 1945. (The wings of the Douglas D-558-1 Skystreak were also straight.) When the Army Air Technical Service Command awarded Bell the contract in March 1945, its engineers had already been briefed by wing sweep champion Robert Jones. But when word came back from Braunschweig, Army Air Forces General Alden R. Crawford accused the NACA of incompetence for not insisting on swept wings. The NACA responded by claiming prudence and pointed to the dearth of experimental evidence, especially at low speeds. A few who witnessed the petty spats between the two organizations later in the program have suggested that the NACA knew better but was determined to give the Army *exactly* what it asked for, which was a straight-wing, rocket-propelled airplane, instead of the turbojet-powered design that the NACA favored. Whatever the reason for them, the straight, thin wings that carried the X-1 blithely past Mach 1 proved there was more than one way to skin a cat (see "Don't Make Waves," p. 71).

One advantage straight wings had over swept-wing designs was rigidity: the more radically a wing was swept, the less torsionally rigid it became. This is why early swept-wing jets sometimes suffered "aileron reversal," which was probably one source of the common misconception—helped along by Hollywood and the mid-1950s English classic film *Breaking the Sound Barrier*—that "the controls reversed" as an airplane approached the speed of sound.

When the right aileron, say, on a weak-winged fighter such as the McDonnell F3H Demon was deflected upward at subsonic speeds, it would, as expected, command a roll to the right. But at near-supersonic speeds air pressure against the raised right aileron instead warped the trailing edge of that wing *down*, thus turning the entire right wing into an enormous aileron that commanded a left roll, to the pilot's bafflement. Some airplanes could literally perform aileron rolls in the direction opposite full stick deflection, and F3Hs were known to return from combat practice maneuvers with permanently warped wings.

The solution to the problem was to design wings with greater rigidity. The English Electric Lightning, although sounding like a household appliance, somehow achieved adequate rigidity despite an enormous amount of wing sweep: a 60-degree angle between the leading edge and a line perpendicular to the fuselage centerline. Only a single Soviet fighter—the Sukhoi Su-7—and delta-wing aircraft such as the Concorde ever equalled or exceeded the Lightning's arrow-shaped sweep.

Even fewer have equalled the Lightning's ability to go supersonic in level flight without using afterburner, a talent so rare, in fact, that it wasn't until September 1989, 35 years after the Lightning first flew, that an experimental F-14 Tomcat with a special engine demonstrated "supercruise"—supersonic cruise without afterburners—for the first time. And that happened only after the aircraft was boosted past Mach 1 on full burner.

In 1953, one year before the English Electric Lightning did it, the North American F-100 Super Sabre became

NASM

The quest for speed in the 1950s fostered novel research methods and bizarre aircraft. Launching F-102 models on rockets (left), the NACA verified the Area Rule. The bullet-like LeDuc 022 (above) tested ramjet propulsion for the French.

the first fighter in the world to fly faster than sound in level flight, though by benefit of an on-or-off afterburner that in a single unthrottleable torrent of kerosene raised the engine's thrust by half. The pride of the U.S. fighter fleet in the mid-'50s, the F-100 demonstrated how little could even then be taken for granted about supersonic flight.

North American was desperate to get the F-100 into production, so when Air Force test pilot Pete Everest turned down the Super Sabre as having some unacceptable handling qualities, North American put the brute in the hands of a group of young tigers from the Tactical Air Command. They all thought it was neater than a wet T-shirt contest and far more exciting than the F-86s they'd been flying. The Air Force's claque outvoted Everest, and F-100s started coming off the production line.

In 1954 they also started coming apart, killing five pilots, including the North American factory test pilot who'd okayed the airplane in the first place. It turned out the original F-100A Super Sabre had such a long, heavy fuselage atop short, heavily loaded wings that it wanted to go sideways or tumble—or preferably do both at once, called "yaw coupling." And when it inevitably did, the resulting force tore off the vertical tail. Later models were given a larger and considerably stronger tailfin.

The transonic regime was still a mysterious one in the 1950s. Airplane builders confronted it by equipping their machines with enormous engines and afterburners, and designers expanded wings into full deltas or shrank them into short, skinny vestiges of wings like those on the F-104 Starfighter, Lockheed's missile-with-a-man-in-it. But sometimes even this combination of brute force and creative extremes was not enough to wrest speed from an unwilling atmosphere, and in 1952 Richard Whitcomb discovered why.

Whitcomb, one of the most productive transonic aerodynamicists in the world, would go on to develop Whitcomb winglets—the vertical wingtip extensions seen on advanced transonic aircraft from the 747-400 to recent Learjets—and would play a major part in the development of the supercritical airfoil for more economical transonic cruise. As Adolf Busemann, the German inventor of the swept-wing concept, once said of Whitcomb, "Some people come up with half-baked ideas and call them theories. Whitcomb comes up with a brilliant idea and calls it a rule of thumb."

Shock stall—the effective loss of lift caused by supersonic perturbations on the wing—is one of the two Katies barring the door to supersonic flight. The other is wave drag—the increase in air pressure, or resistance, against the entire airframe shouldering its way through transonically compressed air. Vintage aeronautical engineering had concerned itself almost entirely with airfoil cross-sections, as though the wing was the only significant part of an airplane and was simply a three-dimensional extension of a two-dimensional curve. As airplanes began to probe the transonic region, designers realized the wing had to be studied as a whole—that its sweep, shape, structure, and aeroelasticity all had to be considered together.

And now, as true supersonic flight revealed a whole host of unexpected control, flow, and drag problems, designers discovered that every external component of the airframe—wings, fuselage, tail, engine pods, intake ducts—affected the others so strongly that the entire vehicle had to be studied as a single entity.

Whitcomb's Area Rule was the first major outgrowth of this revelation, and the need for it was demonstrated by one of the great slips 'twixt aviation's cup and lip, the Convair F-102. The F-102, the first U.S. pure-delta design put into production, was based on some German World War II research and wind tunnel data on components. Unfortunately, the wind tunnel data was incomplete—"perhaps the most outstanding case in the history of aviation of full-scale drag proving to bear little relation to drag

NASA/LANGLEY

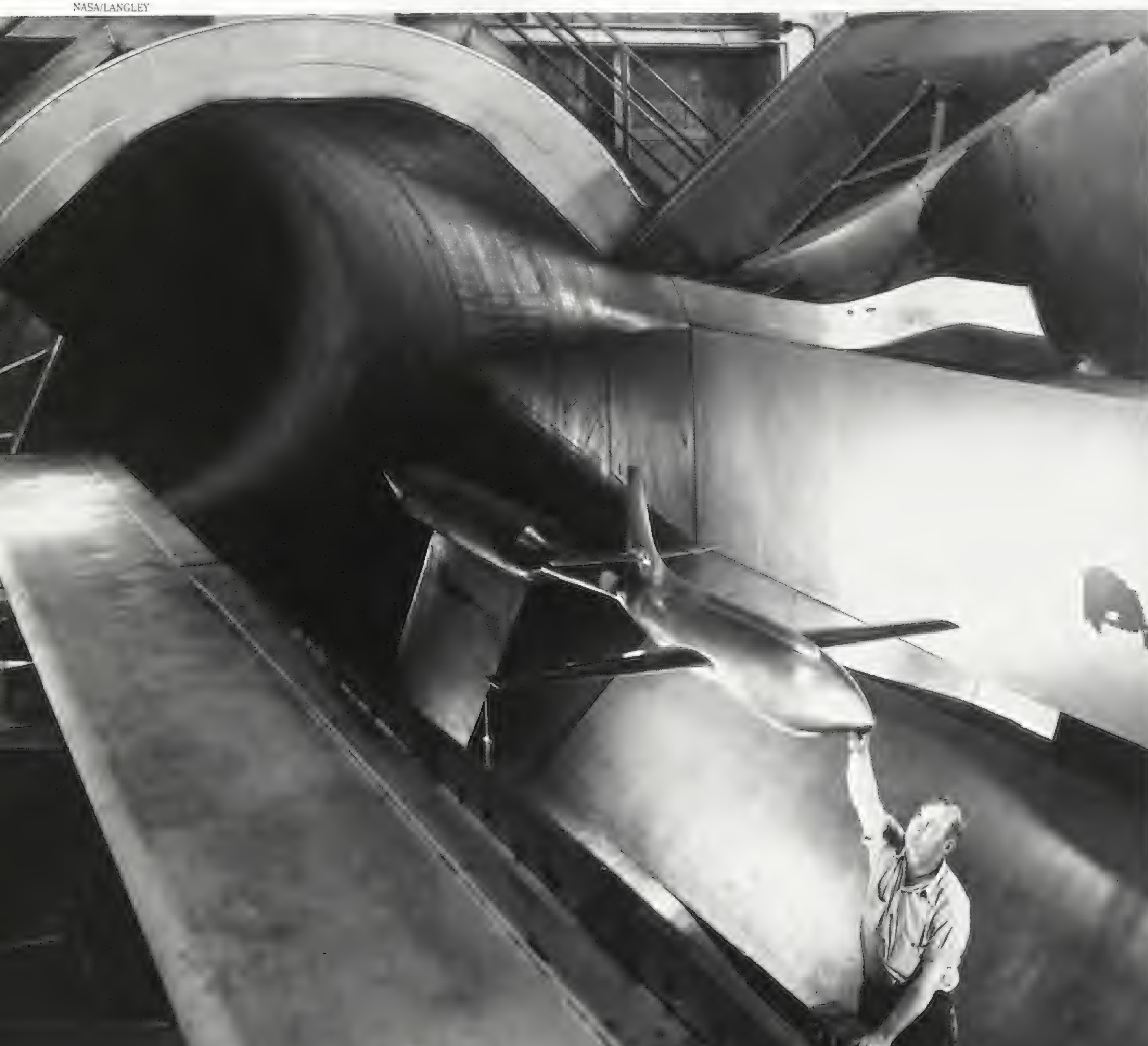
measured in the wind tunnel," says writer Bill Gunston. There was no way the supposedly supersonic F-102 could get anywhere near Mach 1.

What was creating the unexpected drag, it turned out, was a considerable mismatch between fuselage and wing. Whitcomb's brand-new Area Rule said that if you graphed the area that an airplane presented head-on to the air, along an axis extending from the tip of its nose to the end of its tail, the resulting line, a measure of square footage at each point, should come out as a smooth curve. Spikes in the curve, created by the sudden addition of a wing to the cross-section just where the fuselage was fattest, say, meant enormous drag.

The easiest way to flatten such spikes was to locally decrease the fuselage cross-section if that's where the wing needed some breathing room. The result was the grotesque wasp-waistedness of the hastily modified production F-102 and its far faster successor, the F-106. The similarly Coke bottle-shaped Grumman F11F Tiger was the first airplane to be designed

The NACA got its wind tunnels up to speed to test a Bell X-1 model only after the real thing flew past Mach 1.

NASA/LANGLEY



Area Ruling the F-102

Before

After

Don't Make Waves

Paradoxically, many efforts at achieving supersonic flight have been directed at delaying it—at least in those instances in which the airflow goes supersonic in isolated areas over the airframe before the whole thing has reached Mach 1. In the 1940s airplane designers created new aerodynamic configurations, all intended to take it easy on the air to enable a more gradual transition from subsonic to supersonic speed. Thin airfoils, swept wings, and, later, specially shaped airfoils labeled "supercritical" have been used on high-speed aircraft just to keep the airflow well adjusted.

The air's *gradual* adjustment to an aircraft barreling through it is the key to Richard Whitcomb's discovery of the Area Rule and also explains how airfoil shapes can delay the formation of shock waves. Studying the position of shock waves in Schlieren photographs of models in wind tunnels, Whitcomb saw that air flowing around an airplane was being violently shoved aside when it reached the intersection of the wings and fuselage. He realized that it was the abruptness of the increase in area at this intersection that caused the shock waves to form. By narrowing the fuselage at this point, Whitcomb was able to achieve a more gradual displacement of the air and therefore a decrease in its resistance. He formulated the Area Rule, which calls for only gradual changes in the area that an airplane presents head-on to the air.

Convair was the first to apply the Area Rule. In 1952 wind tunnel tests showed that the F-102, despite having a powerful engine and knife-edged delta wings, could not reach supersonic speeds because of high drag. On Whitcomb's advice, the Convair designers transformed the bullet-shaped YF-102 into the slim-waisted YF-102A, creating a faster airplane.

The shapes of wings also changed to keep the air from performing as much work at high speeds as it had been expected to perform at lower speeds. A thin airfoil, for example, decreases the distance that the air must flow over the wing compared with the distance that the air travels under it and therefore reduces the speed of the air over the wing. The idea behind a thin wing is to reduce the ratio of the wing's thickness to its "chord"—the distance from the leading to the trailing edge.

Sweeping the wing back has the same effect as reducing the ratio of thickness to chord and therefore also requires less work from the air. Since a swept wing meets the air at an angle, the distance the air must travel from the leading edge to the trailing edge of the wing is longer, and its acceleration is more gradual.

The supercritical airfoil is a much more recent invention, again by Richard Whitcomb, for delaying the formation of shock waves. The airfoil gets its name from the term "critical Mach number," the speed, usually around Mach .7, at which the first shock waves appear on an airplane's wing. Whitcomb found that by flattening the upper surface of the wing, he could both weaken the shock waves and push them aft to a point closer to the wing's trailing edge. Reducing the camber, or curvature, of the wing also sacrifices lift, however. Whitcomb counteracted this effect by increasing the camber of the trailing edge. With a supercritical airfoil, the airplane can boost its critical Mach number; that is, it can fly faster without the loss of lift and increase in drag caused by the formation of shock waves close to its wing's leading edge.

Classical Airfoil

Supercritical Airfoil

from inception to take advantage of the Area Rule and as a result was the first Navy line aircraft to pass Mach 1 in level flight.

In an era when prosperous airline passengers can fly at twice the speed of sound, aerodynamicists have learned a lot about supersonic flight. But even if the sound barrier is down, the lift spoiler remains. It limits practical flight speeds nearly as firmly as did that imaginary sonic wall. To fly faster than sound—to achieve lift despite shock spikes and to shove aside wave drag—requires massive doses of power or fuel or money. Or, more likely, all three.

In the 1960s, brute force and extreme airframes vastly boosted fighter speeds, and soon everybody—French Mirages, Swedish Viggens, Soviet MiGs, U.S. Century Series jets, even bombers—was routinely doubling the Mach. But after it was discovered that airplanes could fly at two, three, even four times the speed of sound, a strange thing happened: for the first time in the history of flight, designers applied the brakes. Today we are flying slower than we were 20 years ago.

The cream of our military crop, although capable of much higher speeds, clusters on the classic transonic band, cruising and maneuvering at between Mach .8 and 1.2. For commercial aviation, the infrastructure is already far behind the airplane. The complexity of air traffic control, the congestion of runways, the limited access to airports, and the economics of what is becoming a 21st century mass-transit system have made supersonic flight with foreseeable technology irrelevant for all but the most limited and premium applications.

The need for speed seems to have been satisfied. Perhaps. But maybe this is just a Mach .8 plateau, where we rest and await the development of aircraft shapes that create comfy little low-drag shock ripples rather than waves; of airfoil curves that produce lift without sonic drag; of airplanes that reflect all their booming shock-created energy up, toward noiseless space.

A well-known aerodynamicist and aviation entrepreneur who is either laughably optimistic or an unrecognized visionary recently insisted all this was possible. Then he told the story of an orphan he adopted some years ago. When he first met the child, he asked what the boy wanted to be when he grew up. "Oh, I can't tell you that," the boy said. "It might not have been invented yet."

Not So Fast

Until the Navy develops supersonic submarines, Mach number will inevitably apply to objects zipping through the atmosphere. (A space vehicle might travel leventy-leven thousand miles an hour, but it'll never break Mach 1 Out There: there is no sound, ergo, no speed of sound, in the vacuum of space.) But strictly speaking, Mach number is the ratio of the speed of an object to the speed of sound in whatever medium it's traveling through. So Mach 1 for a bullet going through a bar of soap or a nail being hammered into a two-by-four by a particularly powerful carpenter will be quite different from Mach 1 for Tom Cruise buzzing the Miramar Tower.

Sound's speed also changes with the temperature of the air, not simply its density, and though it's typically about 742 mph at sea level, the strongest shout will generally travel only 661 mph anywhere between 36,000 and 60,000 feet, the band of pre-stratospheric tropopause at which air temperature normally remains constant.

To further complicate matters, it now turns out that H.C. Hardy, the physicist who established those specifics in 1942, based them on a dose of . . . well, maybe not bad air, but some pretty ordinary atmosphere literally picked up from a breeze through his lab window. Recent work by George S.K. Wong of the National Research Council of Canada has determined that the speed of sound at standard sea level conditions is not 741.5 mph but 741.1. "You know physicists," Wong said. "They always calculate things assuming this, assuming that. Unfortunately, he did not know how reliable his corrections were."

FRANK MORMILLO

On fast aircraft such as the Mach 1.6-capable T-38, pilots barely notice their passage through the transonic band.


5
3
1
2
4

Disaster at the Cosmodrome

In the early days of the Soviet space effort, the illusion of perfection had to be maintained at all costs. Now we know that the cost was measured in lives.

BRIAN SULLIVAN

by James E. Oberg

The bodies that could be identified numbered several dozen, including that of the officer whose poor judgment had caused the disaster. They were shipped home from the Soviet central Asia launch site for individual interment. Dozens more were burned beyond recognition in the horrible conflagration, and whatever remains could be found—teeth, charred leather, shards of bone, keys and coins—were swept up from the scorched concrete, placed in a single coffin, and lowered into a grave in a park in the rocket workers' city of Leninsk.

The families of these Soviet rocket workers were alone in their grief. Officials quickly announced that the commander had died in an airplane crash. As far as the rest of the world knew in that fall of 1960, the Soviets' efforts in space continued to move from one dazzling success to another.

European journalists in Moscow soon picked up rumors that a gigantic rocket had exploded "in Siberia," killing hundreds, but those stories quickly took their place amid other oft-embellished legends of dead cosmonauts, super weapons, and similar folklore. U.S. intelligence officers had something more concrete: several blurred, spotty photographs of the site brought back by a Discoverer recoverable reconnaissance satellite. ("The scorched area

was tremendous," one officer told me two decades later, shaking his head.) But at the time they were as quiet as the Soviets about their findings. Something horrible may indeed have happened, Western experts concluded, but there was no way to be sure what it was.

Time passed. The gravesite in the Leninsk park was covered with a grassy

VITALY MYAGKOV (2)

mound 40 feet across and fenced in. Local officials erected a memorial obelisk, with 54 name-bearing plaques spaced along the four sides of its square perimeter. Friends, relatives, and co-workers at the Baikonur Cosmodrome launch complex kept the memorial decorated.

Other disasters occurred at the Cosmodrome from time to time, and new memorials were added to the park. One touching tribute was built in a corner of the spaceport's museum—until recently kept secret from outsiders both Soviet and foreign—where a scorched notebook found on an engineer's body was displayed behind glass. No label was necessary. Over the decades the local rocket workers, who knew the Cosmodrome's full history from first-hand accounts of survivors and family members, wore the wooden case smooth with their hands.

The recent opening up of the Cosmodrome to outsiders also opened up many of the workers' bitterness at the decades of official denial. "If you only knew of all the explosions and deaths," one museum official lamented to a visitor earlier this year, "you would be horrified at the size of the deceptions." Evidently much more is still held in secret Soviet archives or, worse, was documented in records the museum staff was regularly ordered to destroy. But none of those later accidents at the Cosmodrome (or another that killed 50 men at the Plesetsk rocket center north of Moscow in 1980) ever approached the death toll of that October evening only three years after Sputnik 1.

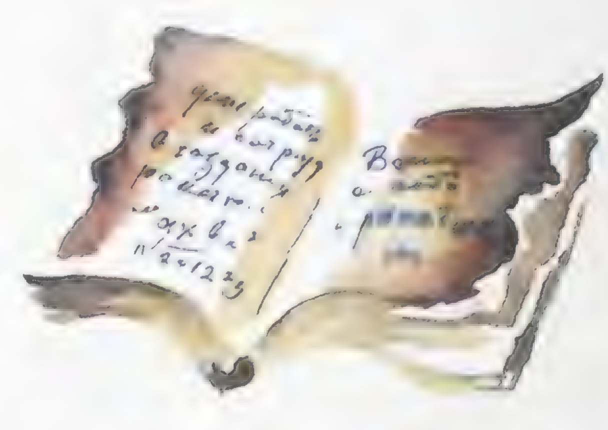
Over the years, many conflicting accounts of the disaster reached the West. As a lifelong space nut fascinated with Soviet mysteries and the sleuthing needed to unravel them, I collected and evaluated the stories and tried to fit the pieces together for more than a quarter of a century. Details came from credible Soviet sources both inside the U.S.S.R. and overseas. Top-level spy Oleg Penkovskiy, executed in 1965, wrote in his memoirs that a "nuclear-powered" missile had exploded, and many recent Russian émigrés elaborated on the theme (apparently basing their reports on the coincidental deaths of several top Soviet nuclear weapons experts elsewhere that October). Émigré Zhores Medvedev, who had a record of correct assessments, reported that the disaster involved a "moon rocket" needed for a propaganda spectacular. Nikita Khrushchev himself mentioned the disaster in the first volume of his memoirs, smuggled out of the Soviet Union and published in the United States in 1970, but he gave no hint of the role he may have played.

From these stories a scenario emerged. Late one afternoon a rocket's countdown was halted when problems cropped up. The launch team, ordered outside to attempt repairs, mounted the scaffolding around the balky, fully fueled missile. Suddenly the second-stage engine ignited, bursting the fuel tanks of the first stage and covering the launch pad in a tidal wave of flame.

In my books, articles, and lectures, I labeled the event "the Nedelin Catastrophe." If any one man deserved such an eponymous disaster, it was Field Marshal Mitrofan Nedelin, then 54 years old. The commanding officer had violated all standards of safety when he ordered the technicians onto the launch pad. Perhaps to support his order he went outside himself, and he died with the others when the missile exploded.

I tried to add it all up. I knew that two unmanned Mars probes had been unsuccessfully launched only two weeks before from the pad used to launch Sputnik, and I believed that the basic Sputnik booster, the R-7, was the only big Soviet rocket flying at the time, so I postulated that the rocket that had blown up was also a Mars-bound vehicle. The Soviets generally prepare three vehicles for any major space effort. The pressure on Nedelin to launch would have been intense: Khrushchev had been at the United Nations in New York earlier that month giving a speech about Soviet foreign policy and anticipating another spectacular feat to flaunt before the world. Furthermore, the launch window—the planetary alignment that allowed such launchings—would have been rapidly closing day by day. That was the scenario I proposed in my book about the Soviet space program, *Red Star in Orbit,* in 1981.

The Mars rocket scenario couldn't account for a few troubling items, however. The ships used to track the Mars probes had been in position in the south Atlantic and northeast Pacific for the failed October 10th and 14th launches, but they had set course for their home ports before the explosion. There were also reports of the involvement of rocket designer Mikhail Yangel, who was not a member of the team behind Sputnik and the two previous Mars shots. Furthermore, the Sputnik pad



was used in a launch only five weeks after the explosion, suggesting little if any damage there. Most tantalizing was the spy Penkovskiy's explicit reference to funerals at a rocket plant in the Ukraine, an installation later revealed to be devoted entirely to military projects.

By the time I updated the account for a new book, *Uncovering Soviet Disasters,* in 1988, my belief in the Mars hypothesis was fading. As the book went to press, I began to regret not offering a

VITALY MYAGKOV (2)

second hypothesis: that the rocket was an intercontinental ballistic missile.

And still I despaired of ever finding out what really happened, short of the violent overthrow of the Soviet government and a personal search through captured top-secret archives. These pages of space history, I thought, were fated to remain blank forever.

But my pessimism was overtaken by recent events in the Soviet Union. In 1989 the first published account of the disaster appeared. A magazine article by Aleksandr Bolotin, a young officer at the Cosmodrome, in the pro-*glasnost* weekly *Ogonyok* identified the rocket as an ICBM. More than confirming my suspicions, the article personalized the horror for me. When it mentioned a memorial obelisk over the burial site, I promised myself that someday, somehow, I would visit it.

Early 1990 found me before the obelisk, reading aloud the names of the dead and placing a bouquet by the stone. Standing there in the mid-winter gloom, brushing the snow off a few of the plaques, I did not feel like the winner in some "pierce the coverup" contest. Rather, I was pleased that after 30 years, a rip in the fabric of reality was finally being repaired. A feeling of wholeness, of a fully restored flow in a history long obstructed, made me proud to have played a small outsider's role in the mending process.

I had arrived at the summit of my investigation thanks to a project on the Soviet space program for PBS' *Nova* television series (to air in the United States this February), for which I served as researcher and on-camera tour guide. Getting to the Cosmodrome last February was difficult, but the crew and I surmounted the bureaucratic obstacles and at last arrived at Baikonur. We asked for a van to take us to the memorial park I'd spotted from the bus on the way in from the airport, and we had to spend half our free afternoon pleading and prodding for it. Persistence finally paid off.

Many of the plaques were cracked with age, but the shrine had not been ignored. Flowers, pine boughs, and tufts of prairie grass decorated many of the markers. I asked my guide who had made these visits so many years after the explosion and his reply caught me by surprise: "Weddings." Since the rocket workers' city has no World War II memorials like the ones newlyweds traditionally visit and decorate elsewhere in the U.S.S.R., the obelisk had assumed the role. Several times a week, groups of young people came on foot from wedding ceremonies in Leninsk to stand by the gravesite, pause in thought, and honor their dead.

But every answer raises another question. I might have taken the 54 names listed there as the total death toll had I not noticed that Nedelin's name was not among them. When I asked my guide why, he replied that the commander's body had been sent home for burial. How many others had been sent home? I asked. The guide thought for a moment. "About 40," he suggested tentatively. The death toll, then, was nearly 100 men.

The details of the disaster were confirmed and elaborated on by the *Ogonyok* article, the only one ever to appear. The designer Yangel was in charge of the technical proceedings at the pad, it said, but at one point he became so nervous he stepped into a special fireproof hut for a cigarette. It was while he was inside that the rocket exploded, probably when a technician plugged the first stage's umbilical cable into the second stage's receptacle, causing a normally innocent command wire to trigger the ignition.

Yangel survived by a fluke. But many of the U.S.S.R.'s spaceflight pioneers perished in the accident. One man named Nosov had pushed the launch button for Sputnik three years earlier; another named Ostashev had been instrumental in developing the Sputnik booster. In Leninsk there are streets named "Nosov" and "Ostashev" among the usual "Marx," "October," and "Red Army" streets.

As I stood before the obelisk, the gruesome details in the *Ogonyok* article came to mind. The explosion had occurred on Monday, October 24, shortly after 6:45 in the evening. One man who miraculously survived gave this account: "At the moment of the explosion I was about 30 meters from the base of the rocket. A thick stream of fire unexpectedly burst forth, covering everyone around. Part of the military contingent and testers instinctively tried to flee from the danger zone, people ran to the side of the other pad, toward the bunker . . . but on this route was a strip of newlaid tar, which immediately melted. Many got stuck in the hot sticky mass and became victims of the fire . . . . The most terrible fate befell those located on the upper levels of the gantry: the people were wrapped in fire and burst into flame like candles blazing in midair. The temperature at the center of the fire was about 3,000 degrees. Those who had run away tried while moving to tear off their burning clothing, their coats and overalls. Alas, many did not succeed in doing this."

Another witness had been on the pad but had finished his work and been ordered away by Nedelin. He went to the observation point on a small hill about two miles away, where a crowd of officers and engineers was relaxing. "Above the pad erupted a column of fire," he recalled. "In a daze we watched the flames burst forth again

and again until all was silent." He rushed to the medical center to help the survivors and found the front of the building surrounded by bodies. "All the bodies were in unique poses, all were without clothes or hair. It was impossible to recognize anybody. Under the light of the moon they seemed the color of ivory." It was a long time ago and the bodies had been at rest for decades, but standing at the obelisk I felt a chill down my spine.

Andrey Sakharov's newly published memoirs add a poignant detail to the tragedy. When the accident occurred, he wrote, "automatic cameras had been triggered along with the engines, and they recorded the scene. The men on the scaffolding dashed about in the fire and smoke; many jumped off and vanished into the flames. One man momentarily escaped from the fire but got tangled up in the barbed wire surrounding the launch pad. The next moment he too was engulfed in flames."

What appeared to be authentic footage of the explosion aired on Soviet television last April 12, "Cosmonaut Day." The films showed a rocket exploding and human figures on fire running and falling. But the horror was not specifically identified or connected with Nedelin, who is still, officially, a hero.

Back at the launch site, Nedelin's memory is not so dear. When I had first asked to see "the Nedelin memorial" I was gently rebuked by my young guide, who hadn't even been born when the tragedy occurred. "The monument is for *all* who died that day," he said. There is no Nedelin Street in Leninsk either.

With these pages of rocket history blank no longer, I mused about the implications of the tragedy. The revelation that the exploding rocket was a military ICBM puts the disaster into the greater perspective of the Cold War. Indeed, it can be argued that the catastrophe almost led to a thermonuclear war.

The Sputnik's R-7 had turned out to be a great booster but a poor weapon. Only four were ever deployed as missiles, at the Plesetsk military center. A second Soviet rocket team was pushing hard for a new rocket to counter the Atlas missiles the U.S. was then deploying. It was that missile, the R-16, that exploded. Flight tests the following year were unsuccessful, probably due to the loss of so many experienced engineers. By early 1962, as Americans began deploying ICBMs in entire squadrons, Khrushchev was faced with a tremendous missile gap.

BRIAN SULLIVAN

It was at this point that he decided to place missiles in Cuba, a gamble that brought the world to the brink of war during the Cuban missile crisis. But as space historian Curtis Peebles recently observed, the strategy would not have been necessary had the Soviets' new missile succeeded sooner.

Those speculations tugged at me as I walked around the memorial square and read each plaque's name. They were all Russian or Ukrainian, and most belonged to 20- and 21-year-old soldiers. I couldn't help thinking that their loss might have been more meaningful had it been for space exploration, the common world struggle that has claimed so many other lives around the planet. But these young men had died building a weapon, not a space probe.

I stood by the cold, lonely graves and tried to imagine the rocket workers' perspective, influenced by wars both hot and cold. They surely thought of themselves as defenders of their nation and as explorers too, since military missiles, such as the R-7, were being diverted to peaceful space activities. For no fault of their own they met a horrible fate. It had been my happier fate to spend three decades wrestling their reality from the denial and distortion wrapped around it. Now their nation was safe, and so was the truth.

Flight School

When flight lands in the classroom, learning takes off.

by Michael Parfit

Photographs by Tom Nebbia

A homebuilt simulator takes Daphne Wilson on a no-frills flight (below).

A pilot as well as a teacher, Iris Harris enlivens every part of her first graders' curriculum with aviation (opposite). For most students, it works wonders.

Over taco meat and chips, several young people pondered the meaning of the exchange *Knock knock. Who's there? Saturday. Saturday who? Let's go out tomorrow and have a Sunday.* One young woman giggled. Then something else crossed her mind. She turned to me and asked, "Is your airplane a taildragger or a tricycle gear?"

Before I could answer, an informal discussion erupted around the table about the relative merits of each aircraft configuration, including a debate over back-country landings and ground handling. Then the young woman's neighbor, who had large gray eyes and a serious demeanor, said, "What I want is a Christen Eagle."

Both aviation enthusiasts were seven years old. But they were not flying prodigies, children of pilots, or military brats. They were first graders at a public school in Fort Payne, Alabama. The reason they knew about taildraggers and Christen Eagles (a sporty single-seat aerobatic biplane) is that aviation is a fundamental part of their curriculum, introduced not just to teach them about transportation but to foster an interest in all aspects of their education.

Something about flying captures kids' imaginations and literally makes them sit up and pay attention. "There's a natural curiosity about aviation among young people in particular," says Phil Woodruff, director of the Federal Aviation Administration's Aviation Education Program.

Teachers all over the United States are bringing aviation into their classrooms. "At our resource centers and workshops we're seeing more and more demand," says Woodruff. "Because we have a unique product in the educational community, more and more teachers seem to be picking up on it." The National Air and Space Museum's Education Resource Center, which provides free materials and curriculum guides, fielded some 7,000 requests for information from teachers in 1989, twice the number received in 1988. The FAA's program, along with NASA and the Civil Air Patrol, sponsors about 250 graduate-level workshops annually, which train up to 8,000 new teachers in incorporating aviation into the learning process.

Although the FAA, the Smithsonian, NASA, and aviation industries support aviation and space education, this movement is not directed from above—it is almost entirely a grassroots activity, born of teachers' perpetual searches for ways to inspire their students. Many begin programs at their schools because of a personal interest in aviation and find that the students respond dramatically. One of the first was Iris Harris' Fantastic Flight program in Fort Payne, which has become a model for schools nationwide.

I met Harris at her Forest Avenue elementary school during the busy week before the school's annual airshow. The whole school was swept up in a carnival of flight. Model airplanes hung in the hallways. Shoe box dioramas decorated with cotton clouds sat on windowsills, offering little windows into life in the sky. Fort Payne bills itself as "the Sock Capital of the World," and in the classrooms children were making wind socks out of paper bags and streamers. In one class the day's chosen student was sitting at the Aviator for a Day desk, which had broad wooden wings. In another, first graders were learning about maps, using pieces of aviation charts. "Can you tell me how many airports there are on your chart?" asked the teacher. In another, the blackboard was covered with spelling words: *airport, hangar, runway, pilot, cloud, land, wind.* "Two kinds of books never stay in the library," says Harris. "Dinosaur books and aviation and space books."

This week of concentration on flight was only the culmination of a year in which aviation had played a large part in the students' overall


Sunday Monday Tuesday Wednesday Thursday Friday Saturday
Sun Mon Tues Wed Thurs Fri Sa
Weather

Field trips to Fort Payne's airport have evolved into an annual airshow (right and below). The flying circus theme also pervades the classroom, where a chosen student occupies an Aviator of the Day desk while the class learns about sailplanes (bottom).

education. "I take aviation and put it into every subject," Harris told me as she walked briskly from class to class. "Instead of Dick and Jane and Spot, we read about helicopters and what they do. We do math that is aviation-related. We use logbooks not only for putting numbers down, but we use them to get them to be neater in their writing. What this program does mainly is make learning fun."

"Language, art, math, science, social studies—it relates to all of them," says Woodruff. "It's a very adaptable subject. It becomes very user-friendly." It's also participatory education. "It's a good motivator," says Jim Fitzgerald, a third-grade teacher in Shaker Heights, Ohio, "because there's lots of hands-on stuff."

Fantastic Flight began with Harris' own fascination with aviation. In 1981, while working on a Ph.D. in elementary education, she signed up for courses at the University of Alabama, then went to a nearby junior college that offered aviation ground school. Soon aviation temporarily edged out the degree. Now she's a private pilot and the owner of a bright yellow Piper J-3 Cub.

At first, flight was an escape. "Working all day long with children can be so stressful," she says, grinning. "You know, you just want to scream, but you have to be nice all the time. Then you can get up there and it is so peaceful and there is no one pulling on you and you look down at God's beautiful green earth." But though flying alleviated the stress of the classroom, it also gave her an idea of how to make the classroom more satisfying, for both herself and the children. "I started showing things about weather, flying, and everything you do in ground school. The interest was incredible."

Harris' talks on her own training grew into an entire program. The first year she capped

her discussions on learning to fly by taking her 30 students to the airport to see an airplane. The next year there were 60 students from two classes, and they saw four airplanes and four skydivers. Today the entire city of Fort Payne practically closes down its knitting mills to attend the school airshow and take in the aerobatics, military aircraft, helicopters, sailplanes, antique and classic airplanes, crop dusters, and skydivers.

Harris gives the children a full-fledged flying circus in which they're part of the act. She invites pilots, astronauts, air traffic controllers, and flight attendants to speak to her classes, and she conducts lessons with propellers on sticks, model aircraft, rockets powered by balloons, and at least one splattery explosion. The pilot who comes to visit explains that he can never be late and why he can never forget his charts and documents. The kids are transfixed by his words, and now maybe they'll come to class on time with their papers. When a pilot explains why she must not take drugs or have a police record, the admonitions of parents and teachers suddenly have a broader meaning.

In 1987 Harris outlined her program in the hefty *Aerospace Curriculum Guide.* The book, initially published by the state of Alabama, was recently reprinted by the FAA's Aviation Education Program. The text is the heart of a series of workshops Harris has given in her role as Aerospace Education Specialist for the state of Alabama, a job she continues while teaching at Fort Payne. During a day-long workshop I attended, Harris and three volunteers, all in blue and white flight suits, demonstrated both the appetizers and the entrées of the program.

"Thrust that piece of paper as hard as you can toward the back of the room," Harris tells two teachers. One has a crumpled piece of paper; the other's is flat. The teachers thrust. The flat page flutters gently to the ground. The wad flies from the teacher's hand and bounces off a colleague's head. "You see,"

It will never orbit Earth, but this low-budget "space station" helps fire students' imaginations.

Harris says, "the flat sheet had much more surface and more drag."

Atop a heated soft drink bottle a balloon slowly comes to attention as hot air rises within it. A paper balloon, heated by a stove, soars to the ceiling. The floor is littered with paper airplanes of various shapes and distinctly varied performances. Teachers make rockets out of inflated balloons taped to straws, and when Harris calls out a countdown everyone lets go of the mouths of the balloons at "zero." With a flatulent rumble a host of rockets leap toward the ceiling.

Near the end of the day two of her assistants—Bob Lock, a Boeing Military Aircraft Company engineer, and Wayne Whisenant, a marketing representative for Atlantic Aerial Survey—put a half cup of water, a half cup of vinegar, and a folded paper towel containing two tablespoons of baking soda in a soda bottle and cap it with a cork. "This is my favorite," Lock says. "It makes noise and it's extremely messy. The kids love it."

Placed on a table, the bottle fizzes like a lit fuse. Everyone stands back. It stops fizzing. The room waits silently. Finally, with a little help from Lock, the bottle pops loudly and, with a satisfying fountain, fires the cork across the room.

All day, while their circus whirls, Harris and her team repeat their theme: this is not just an aviation program, it's a way to encourage learning in general. By describing his early

designs of helicopters, you get a child thinking about Leonardo da Vinci, "and now that you've talked about Leonardo," Harris says, "you can plug him into art, plug him into reading." Ask a child to imagine how she is going to fly from one point on an aviation chart to another and then ask how she determines if she has enough fuel to get there. "Two hours plus two hours to fly here is better than two apples plus two apples," says Jack Barker, public affairs officer for the FAA's southern region.

Fantastic Flight also relies on volunteers. A few years ago Harris asked for something that might have cost thousands of dollars: a simulator that a child could sit in and use a control stick to turn, bank, and raise and lower the nose. Members of the local Experimental Aircraft Association chapter built her a rudimentary simulator. Dozens of copies, built from the EAA designs, are now under construction for classrooms across the country.

Of course, one question dogs all this enthusiasm for a new process in the old mystery of education: Does it work? "When aviation is in the curriculum there are definite cases of very dramatic improvement in every tested category across the board," says Phil Woodruff. "It's one of those things that just work in the classroom." This kind of success was evident at Fort Payne, where Fantastic Flight has helped push last year's second grade achievement test scores about 20 percent above national averages. Its effects on long-term motivation and dropout rates aren't yet known, although Harris, with typical enthusiasm, hopes that junior high students at high risk of dropping out will remember the days when they met astronauts and pilots and decide to stay in school. "It's like our accident prevention program," says the FAA's Jack Barker. "You can never say 'How many accidents did we prevent?' "

The day after visiting Harris I took off from Fort Payne's airport late in the afternoon. Long shadows were spreading over the last deep glow of sunlight. The sock factories were empty and the homes were full. Across the land, people were sitting down to dinner. As I flew over Forest Avenue elementary, I waggled the wings, then looked at my aviation chart and, like a first grader, calculated my fuel to the next stop.

Astronaut Frederick Gregory, star of last year's airshow, signs off on his fans (above).

Allison Gamble displays a true agricultural aircraft—one made from a potato (left).

Freed from the constraints of the classroom, students turn a sidewalk into a canvas that illustrates the history of flight (opposite).

NATIONAL LIBRARY OF MEDICINE

X-rays were discovered in 1895, and within a year physicians such as William J. Morton were using the mysterious form of energy to produce arresting images of the human body (left). In the 20th century, scientists discovered subjects that provided their own X-ray illumination; the picture at right, taken last year, is the clearest image of the sun's X-rays made to date.

Evidence of Cataclysm

The hunt for extraterrestrial X-rays was a tale of gambles, misfires, and unsettling surprises.

by George Greenstein

Danger Islands, October 12, 1958, noon: In the next few moments, a total eclipse of the sun will begin to blacken the skies above these tiny South Pacific islands. About 25 miles off the coral atoll of Puka Puka sits the small-craft landing ship USS *Point Defiance,* and on its small helicopter deck stand six dart-shaped Nike-Asp rockets.

The rockets have been equipped with devices to detect the presence of X-rays. As the eclipse begins, technicians scurry across the deck to rip away the plastic sleeves protecting the detectors from the sea air. Then they race to a ladder leading off the deck. The rockets are about to be launched. Each has the force of a 1,000-pound bomb.

As the sky darkens, the first rocket blasts off from the deck. Then the second, the third, the fourth. But when the button is pushed for the fifth, nothing happens.

Scientists watching from the deck below are frantic. In order for their experiment to succeed, the rockets must be launched throughout the eclipse's entire progression.

Finally technicians identify the problem: the blasts from the first four rockets have loosened the plug that transmits the launch signal to the fifth. One of the scientists hurries up a ladder to the deck, climbs the tripod on which the fifth rocket is mounted, and reinserts the plug. Then he scrambles for cover, ducking behind a gunmount parapet 50 feet away.

Again, nothing.

The scientists make a quick decision to move on to the last rocket. But this one too refuses to ignite. The man on deck dashes out from the parapet, again clambers up the tripod, adjusts the plug, and races for cover. Once more, the launch signal is given.

With a roar, the rocket lunges off the deck.

"It was sort of a gamble," Herbert Friedman admitted years later of his expedition to study the X-rays emanating from the sun. The rocket technology was still under development, and the cost of the project was enormous. "[I]n our own group, I had one key man who panicked over it," Friedman told science historian Richard Hirsh. "He should have been right in the middle of that experiment, and he just couldn't conceive of our going out and trying this. He thought we would have a total disaster. It got to the point where he almost had a nervous breakdown over it, and we left him behind."

Confidence in Friedman's scheme had been low on other, more critical fronts. Friedman had requested funding for the expedition from the scientific review panel of the International Geophysical Year, a global-scale effort to study the earth and its atmosphere. The panel turned him down, believing that the rocket system he proposed using wasn't dependable enough. Fortunately, Friedman, a physicist with the Naval Research Laboratory (NRL) in Washington, D.C., had other resources close to home. "I went to [the Office of Naval Research] and talked to the chief of naval research then, Admiral [Rawson] Bennett, and told him what I wanted to do. We needed a Navy ship. And I

NAVAL RESEARCH LABORATORY (3)

Herbert Friedman's eclipse studies were risky propositions: to aim his rocket payload (above) during a 1964 lunar eclipse of the Crab Nebula, Friedman had to rely on a nighttime-use gyro stabilizer that was far from perfected. The Nike-Asp rockets he launched during a 1958 solar eclipse were likewise unproven (left).

thought it would cost about $70,000 to carry out the expedition. He said, 'You've got the money. Go and do it.' He assigned a ship to us. This was sort of overnight."

The decision proved a wise one. The rare occurrence of a total solar eclipse enabled Friedman to make detailed observations of the sun's corona, a wispy halo-like cloud of gas that is normally hidden by the sun's blinding visible light. And by observing the moon's progressive occultation of the sunspots on the sun's surface, Friedman's Nikes also demonstrated that sunspots are powerful sources of X-rays. The Navy's investment had been repaid handsomely.

X-rays pouring down from the sun don't, on the face of it, sound like something that would command such attention from the U.S. Navy. But in the 1940s and '50s they were in fact critical to naval operations. In those pre-satellite days, long-range radio communication took place via radio waves bounced off the ionosphere, a layer of ionized atoms that commences at an altitude of roughly 45 miles and extends up for several hundred miles. At the time, the presence of these ions presented a major mystery: to ionize atoms, or give them an electric charge, some form of energy is required, and no one was sure what form was producing the ionosphere. Relying on a mystery for communication with its ships at sea made the Pentagon understandably nervous.

Most people believed that the energy producing the ionosphere was ultraviolet radiation from the sun, but Edward Hulburt, the head of the NRL's physical optics division, disagreed. "[I]t was a mystery how the ionosphere was formed because when you looked at the sun, you saw a 6,000-degree [Celsius] black body, and that would not produce enough ionizing radiation," Friedman explained. "Hulburt very early thought there must be something like X-rays from the sun—although he didn't have any idea how they could be produced—because only X-rays would have the right ionizing properties and the right absorption characteristics to produce an ionosphere at the right height."

During the 1940s a few others supported Hulburt's thinking. "There had been theoretical work done by [Swedish spectroscopist Bengt] Edlén, for instance, which strongly implied that there ought to be X-ray emissions from the solar corona," recalled Friedman. "In even the crudest idea of the sun, the corona was thought to be a very extended atmosphere of the sun. In order for it to be that extended, it had to be hot, because it had to compete with the pull of the sun's gravity—hot enough to imply temperatures in the million-degree range. And a million-degree plasma will produce X-rays. The big question was: How intense was the X-ray emission?"

The question couldn't be answered from the ground: any X-rays the sun might be emitting would be absorbed by the atmosphere—indeed, they were absorbed more readily than any other form of electromagnetic radiation. It

would take the close of World War II and the shipment to America of 300 boxcars full of German V-2 parts to break the stalemate.

The Army assembled the rockets and made them available to scientists for experimental purposes (see "Richard Tousey and His Beady-Eyed V-2s," June/July 1986). In 1948 T. Robert Burnight of the NRL used a V-2 to send aloft several packs of photographic film wrapped in thin metallic foil transparent to X-rays. "He detected blackening on the film, which I would have attributed to pressure blackening because of the way he constructed his packets, but he claimed to have detected X-rays," Friedman recalled.

It was another year before Friedman could see for himself whether Hulburt was right. When his chance came to look for X-rays during a V-2 flight, Friedman employed geiger counters, far more sensitive than photographic film. A geiger counter is a box containing some gas and a wire. Friedman's had a foil window that blocked visible light but permitted other forms of radiation to pass through. If radiation entered the box, it would ionize the gas, setting off an electrical pulse in the wire that would be telemetered down to earth. Friedman prepared several counters, each with a window of different thickness so that different electromagnetic wavelengths could be detected.

The V-2 was launched from White Sands, New Mexico, on September 29, 1949. Had the ionosphere been produced only by ultraviolet radiation, as prevailing opinion held, all of the ultraviolet would have been absorbed high in the ionosphere. But as the rocket rose, it revealed that the strongest ultraviolet wavelengths penetrated to altitudes well below the ionosphere. And as the V-2 continued to rise through and above the ionosphere, the geiger counters began reporting the presence of X-rays. Rounding out the picture, photocells sensitive to visible light confirmed that the X-rays were received only when the counters pointed toward the sun.

It took a rocket coupled with a balloon to prove that the sun could emit X-rays strong enough to block shortwave radio signals.

COURTESY RICCARDO GIACCONI

Friedman was ecstatic. "In a very simple experiment we answered several of the classical questions about solar radiation and the upper atmosphere.... From that point on I wanted to get rid of all the other things that were absorbing my time and concentrate on this."

The Navy continued to provide him with opportunities to do exactly that. One was solving the puzzle of shortwave radio fade-out. Fade-outs occurred whenever the sun underwent the vast explosions known as solar flares. By the mid-1950s Friedman had come to believe that fade-outs resulted when a new layer of ionized atoms suddenly formed several miles below the normal ionosphere. While the ionosphere bounced back radio waves, this new layer would absorb them.

To determine what caused the layer to form, Friedman needed to make observations at the time a solar flare occurred. But these disturbances are unpredictable events that are over in a matter of minutes; to observe them Friedman had to have a rocket capable of being fired at a moment's notice. Vehicles such as the V-2 were out: they employed liquid fuel, which took too much time to load and could not be stored on board for more than a couple of hours. The only "pushbutton" type of rocket available was the solid-fuel Deacon, and Deacons could barely reach an altitude of 25 miles—15 miles short of the new layer.

The ingenious solution to this problem was the "rockoon"—a Deacon rocket dangling from a Skyhook balloon floating 17 miles up. Upon a radio command from below, the rocket would fire and climb to well above 60 miles to perform its observations.

The NRL group's launching platform was the landing ship USS *Colonial*, which dropped anchor several hundred miles off the coast of Southern California in 1956. On board, Friedman was in teletype communication with two observatories, the Sacramento Peak Observatory in Arizona and the High Altitude Observatory in Colorado, both of which monitored the sun continuously. If either were to notice a solar flare it would immediately alert Friedman, who would give the command to fire the rocket. The team had 10 rockoons.

Each morning the team released a rockoon and waited for a flare to be reported. If no flare had occurred by the end of the day, the rocket had to be ignited anyway, before it could drift off and become a menace.

The first two days, the sun was dormant. To make matters worse, when the crew tried to bring down the Deacons, it had no luck igniting them. "In its military version [the Deacon] was fired at normal atmospheric temperature and pressure from the ground," Friedman explained years later in his book *The Astronomer's Universe*. "But that ignitor refused to function in the frigid thin air at 25 kilometers. Jim Kupperian, who recalled some juvenile experience mixing saltpeter and charcoal to make gunpowder with a junior chemistry set, volunteered to serve as our pyrotechnics expert. It must have appalled the ship's gunner's mate to watch such amateurish fiddling with explosives, but after a couple of disappointments

NAVAL RESEARCH LABORATORY

Riccardo Giacconi (top, at left) studied cosmic rays at Princeton before turning to X-ray astronomy.

Using a pinhole camera lofted on an Aerobee rocket in 1960, Friedman's group snapped the first picture of the sun's X-rays (above).

NAVAL RESEARCH LABORATORY

Kupperian found the right formula and his ignitor fired successfully."

But one problem couldn't be solved: in Friedman's words, "the sun refused to cooperate and remained disappointingly quiet." Each day, the NRL people wandered disconsolately about the *Colonial*, eyeing their ever-dwindling supply of Deacons. On the fourth day, a Sunday, the team took a break from the launch schedule—and missed two strong flares.

Finally, they received word that a weak solar flare was starting. A Deacon was fired, and as it climbed into the upper atmosphere, it sent back data indicating that an intense flood of X-rays was pouring down through the ionosphere. Calculations based on the quantity of X-radiation detected soon revealed that solar flares are immensely hotter than the sun's 6,000-degree surface: they may reach temperatures of 20 million degrees.

It had been a nerve-wracking experiment, but within a year Friedman was ready to take up the hunt once more, this time 7,500 miles away, where for a few rare minutes above the South Pacific's Danger Islands, the sun would reveal more of its secrets.

Aerobees and their parachute-equipped detectors proved a boon to the NRL team, who used them in the 1960s to scope out X-ray sources throughout the Milky Way.

A year after Herbert Friedman's solar eclipse expedition, Bruno Rossi decided to throw a party. Rossi was a professor of physics at the Massachusetts Institute of Technology and chairman of the board of American Science and Engineering, a contract research firm based in Cambridge, Massachusetts. One of the people he invited to his party was a new AS&E employee named Riccardo Giacconi.

In his native Italy Giacconi had done a thesis on cosmic rays. From there he had moved on to Indiana University and later to Princeton. Today, he recalls

those days as periods of mounting frustration. He was trying to identify particles produced when high-energy cosmic rays collide with atoms in the atmosphere—work that could have been better accomplished in one of the particle accelerators being developed at the time. But the teams that worked with the accelerators tended to be large, and as Giacconi told Wallace and Karen Tucker, the authors of *The Cosmic Inquirers,* "I wasn't really that eager to go into large groups. I wasn't doing very well. Nothing I had done in science was really of great significance."

Such was his frame of mind as he drove to Rossi's party. Rossi was one of the premier physicists of his day: an Italian like Giacconi, he had made his mark in cosmic ray physics and taken part in the Manhattan Project. At the party, Rossi suggested to Giacconi that he go into X-ray astronomy.

Giacconi would later come to think of Rossi's advice as "a seminal suggestion, which all of a sudden gave me a way to go." Working with AS&E colleague George Clark and MIT's Stan Olbert, Giacconi quickly made estimates of possible X-ray sources outside the solar system. "The estimates were necessarily very uncertain," he later wrote, "but it seemed highly unlikely that the existing detectors would pick up any x-rays from these sources."

Giacconi ultimately decided to search for X-rays from the moon, which should be produced when high-energy solar particles slammed into its surface. The emission, in theory intermediate in intensity between those of the already-studied sun and the hard-to-study stars, might turn out to be observable.

But the moon's X-rays were likely to be swamped by a greater flux of cosmic rays—energetic particles that are capable of triggering spurious signals in a counter—so the team needed a detector that was more specific than those flown before. They decided to include a second counter, one that was sensitive to cosmic rays but insensitive to X-rays, and an "anti-coincidence" logic circuit, which would report the detection of X-rays only if the first counter fired while the second did not.

Bruno Rossi (below left) worked with Enrico Fermi (right) on the Manhattan Project before joining AS&E, where he promoted the new science of X-ray astronomy.

COURTESY BRUNO ROSSI

The first flight, on a Nike-Asp scheduled for launch in June 1960, failed when the rocket misfired. Another flight was arranged for the following year, and in the interim the team continued to improve their detector. They exploited new technologies to construct mica windows a mere few thousandths of an inch thick, which were far more transparent to X-rays. And they extended the detector's field of view to 120 degrees. The final package represented a hundred-fold improvement in sensitivity over Friedman's detectors.

But when the second rocket, this one an Aerobee, was launched in October 1961, the doors protecting the instruments failed to open when the rocket reached the required altitude. Finally, on the night of June 18, 1962, everything worked smoothly. As this Aerobee rose to an altitude of 140 miles above White Sands, its counters began reporting the presence of X-rays.

Down below, the experimenters were jubilant. But their elation turned to concern when they realized that the X-rays were far more intense than anticipated. "I knew what the rates should have been," recalled Giacconi's co-worker Herbert Gursky, ". . . So I felt we were in trouble, but I didn't know why." When the team studied the data in more detail, they discovered with astonishment that X-rays were coming from somewhere 30 degrees from the moon.

The source of the X-rays was eventually identified within the constellation of Scorpius, and it came to be known as Sco X-1, for the strongest X-ray source in Scorpius. We now know that Sco X-1 lies some 60 billion times farther away than the moon; nevertheless, so gigantic are its emissions that they utterly swamp those from our satellite.

In the years that followed, an intense competition developed between Friedman's and Giacconi's groups. "I did know that AS&E was looking for

The X-ray profile of Vela, the remnant of a star that exploded 6,000 years ago, was captured by the Einstein orbiting X-ray telescope, launched in 1978.

DANE PENLAND, FROM PAUL GORENSTEIN, CFA

lunar X-rays," recalled Friedman. "I felt that was a futile effort . . . . And I guess I didn't realize that if they continued to do that they would automatically stumble on the galactic X-ray detection. So it was a surprise when Giacconi reported that result. And the only important reaction we had was: Well, let's go ahead and do what we were planning to do—that if the AS&E result was a true detection of galactic X-rays, we would do better with a bigger counter." Within a few months Friedman discovered a second X-ray source, the exploded-star remnant Crab Nebula, and he confirmed and elaborated on Giacconi's finding.

He had come close to discovering Sco X-1 himself. As far back as 1956, in the course of one of his rockoon flights, he had found indications of a flux of X-radiation coming from some object other than the sun. "The detectors were scintillation counters which had no directional sensitivity, so we couldn't tell from where the X-rays came," he recalled. "With hindsight I realized later that was the first detection of galactic X-ray emission. I thought then it was a possibility and reported it as such, but with great reservations because we had nothing in sound theory to lead us to expect that we could find that kind of galactic X-ray flux." (Giacconi, for his part, puts a slightly different spin on the story in *The X-Ray Universe*, which he co-authored with Wallace Tucker: "Herb Friedman was in the audience and heard Giacconi describe the discovery of the first source of x-rays outside the solar system, a source that was just below the level of detectability of a search made by Friedman's NRL group a few years earlier . . . . Clearly they had just missed making this discovery.")

The competition between Giacconi and Friedman was in turn driven by another: the Cold War. Friedman, whose South Seas expedition had failed to win financing from the International Geophysical Year in early 1957, noted that after the Soviets succeeded in orbiting Sputnik 1 several months later, "[s]uddenly research money began to flow again." Giacconi's company also profited from America's anxiety. In October 1961, shortly after President Kennedy decided that the United States needed to begin testing nuclear weapons, the Air Force Cambridge Research Laboratories in Massachusetts approached AS&E about developing a program to measure the effects of nuclear weapon explosions at high altitudes. Money was no object. Since thermonuclear weapons detonated in the vacuum of space would release intense floods of X-rays, AS&E must have found the offer appealing. In less than a year, the staff expanded from half a dozen to over 70. They designed, built, and launched 24 rocket payloads to measure X-rays and other forms of radiation in space.

But these instruments, as well as later X-ray hunters such as the 1970 Uhuru satellite and the 1978 Einstein orbiting telescope, did not make things clearer—they made them more confused. More and more sources of X-ray energy were discovered lying beyond the bounds of the solar system, and it eventually became apparent that these mysterious objects were not aberrant interlopers on the astronomical scene—they were part and parcel of its workings. A new and utterly unexpected universe lay waiting to be explored.

By now, X-rays have been detected emanating from the debris of supernovae, cataclysms in which entire stars are exploded into shreds; from torrents of material plummeting downward onto black holes and ultra-compressed neutron stars (which Sco X-1 turned out to be); from the brilliant but ill-understood quasars; from superheated gas filling the voids between galaxies. X-ray astronomy, in short, has helped to show that the view of the universe as it appears to us on a clear night—motionless, serene, eternal—is wildly wrong. The cosmos is racked by convulsions far more violent and more common than had ever been thought possible.

The pioneers of this science had forged ahead against widespread indifference in the astronomical community. With the advantage of hindsight we are tempted to look back on the naysayers with amusement and contempt. But nothing that was known in the early days gave the slightest indication that astronomical objects emit significant quantities of X-rays. X-ray astronomy is possible only because the cosmos has turned out to behave in ways that no one, not even the discipline's pioneers, could have foreseen.

On a clear, crisp November day in 1948, at Bradley Field outside Hartford, Connecticut, Ann Griffin climbed into the open cockpit of a bizarre machine, a skeleton fabricated of pipes and perched upon three wheels. Dressed in dark slacks, a light-colored tunic, and leather gloves, with a small cocktail hat pinned to her neatly coiffed hair, the young woman from nearby Simsbury looked confident. But as the Kaman Aircraft K-125's engine came up to speed and its dual intermeshing rotors whipped through the air above her head, Griffin's expression betrayed her, revealing more than a touch of anxiety.

Griffin's fear was entirely understandable. After only two hours of ground instruction and a mere 36 minutes in the air with Kaman test pilot Bill Murray, this housewife, with no

NASM

The Taming of the Copter

Helicopter designers face some baffling technical challenges. Charlie Kaman was never baffled for very long.

by Jay Stuller

KAMAN CORPORATION

Hovering above a film crew in Hartford, Connecticut, a Kaman K-125 shows off its manufacturer's hallmark design: dual intermeshing main rotors and no tail rotor. An early advertisement (above) proclaimed the K-125's ability to generate more lift using less engine power.

previous flying experience, was steeling herself for her first solo flight.

Griffin had often watched Murray's spectacular K-190 demonstrations, held at Bradley nearly every Sunday. He wore a black leather jacket and a James Dean haircut before Dean was even out of high school, and he would put the novel aircraft through a series of high-speed runs, pull-ups, and sideways

maneuvers, then land with the engine off, letting the rotor blades auto-rotate.

Griffin's trepidation when it was her turn to fly no doubt stemmed partially from the presence of several newsreel cameramen and photographers, including a contingent from *Life* magazine, who were scrambling to capture images of her inaugural flight. But all went well as she lifted off, rose 50 feet into the air, hovered for 10 minutes, then landed—her hat safely in place.

Standing off to the side through it all was the architect of the publicity stunt. Tall, burly, and only 29 years old, Charles H. Kaman was hoping that lofting the housewife into the sky would help him to prove a point. At a time when most rotary-wing craft were highly unstable—often shaking, shuddering, and testing the nerves of even an accomplished pilot—Kaman contended that an untrained person could successfully fly and control his K-125 helicopter with less than an hour of instruction. He also hoped that the national attention that was now focused on Ann Griffin would draw new investors to his financially tailspinning company.

Kaman had plenty of competitors in similar straits during the late 1940s. Most were small firms led by aeronautical engineer-inventors like himself. Other helicopter pioneers allied themselves with big corporations, such as Art Young had done with Bell Aircraft and Igor Sikorsky with United Aircraft. Nearly all, including Kaman, promoted the notion that these strange-looking flying machines would soon replace the family wagon or commuter car.

The idea was a seductive one: a person could lift off from the backyard, zip over rush hour traffic, and land at the office heliport, avoiding highway congestion. A trip to an isolated beach or mountain picnic spot would take 30 minutes instead of several hours. And yet by encouraging such a popular fantasy, helicopter entrepreneurs were engaging in a bit of duplicity. While publicly touting the utilitarian benefits of their machines, they privately struggled with the serious technical complexities of rotary-wing flight. The promotions they undertook had more to do with securing investors to fund desperately needed research than with generating sales. For mechanical and aerodynamic reasons, helicopters were much harder to design and build than airplanes.

Fixed-wing aircraft obtain lift by moving through the air, propelled forward by propellers or jets. Air passing over a wing creates a relative drop in pressure across the upper surface, while the air below the wing has a relatively higher pressure. Together with other forces, this pressure difference creates lift. When the wing is angled slightly upward, the air pressure differential, and thus lift, are increased.

A helicopter gains lift in a similar way, but its wings are rotor blades. When the angle of attack, or pitch, of the blades is changed by tilting them upward, they take bigger bites of air, exerting a greater force to accelerate the air downward and leading to surface pressure differential and lift.

This simple concept, however, led to baffling engineering problems (see "The Autogiro and Its Legacy," December 1989/January 1990). When a helicopter engages in forward flight, the flow of air over the advancing blade is faster than the flow over the retreating blade. The air imposes changing loads

KAMAN CORPORATION (2)

Top: So sure was Kaman of the K-190's stability that he put his mother, Mabel, on a demonstration flight. Above: Kaman and pilot Bill Murray (center and right) examine the test rig. Right: Kaman tried unsuccessfully to market the K-225 as a crop duster. Note the servo flaps, easily visible on the blades.

upon the flexible blades, causing them to vibrate. The vibrations are carried down through the rotor hubs, through control linkages, and on to the cockpit, jarring the pilot's controls. Contributing to this problem was the fact that manufacturers were unable to produce blades with precision and uniformity. Blades differed from one another in weight, contour, stiffness, and weight distribution.

Moreover, turning the rotor blades requires tremendous torque, which is produced by the engine. Newton's third law states that every action has an equal and opposite reaction. When a helicopter's engine turns the blades in one direction, reactive torque causes the craft's fuselage to twist in the opposite direction.

The helicopter's torque problem can be eliminated by using two rotors spinning in opposite directions, either on separate shafts or on a co-axial system with one set of blades positioned above the other. Another way to counter torque is to use a tail rotor, which produces thrust like a propeller's to balance the

force of engine torque. Following World War II, leading engineers such as Sikorsky, Young, and Stanley Hiller were generally committed to single main rotor/tail rotor systems.

Although tail rotors consume precious power, they produce no lift. Aircraft engines of the day, not specifically designed for helicopters, could barely lift helicopters off the ground, yet tail rotors were still thought necessary for controlled flight.

Most of the proto-whirlybirds were graceless, unstable, and downright dangerous. The vibrations strained pilots, as well as rotor heads, controls, and other points vulnerable to metal fatigue. And yet Charlie Kaman sat a housewife in the cockpit of the K-125 and sent her up to solo. His helicopter, surely, was different from all the others.

The son of a German-born, Washington, D.C. construction superintendent, Kaman displayed an early interest in aerodynamic design. During the 1930s the city's playground department sponsored model airplane contests, and in 1938 Kaman brought home his first trophy.

While working toward an aeronautical engineering degree at Catholic University, Kaman continued building models. One, made of balsa wood covered by ultra-thin film and powered by a rubber band, took more than 100 hours to assemble. At a competition at Washington's Constitution Hall, Kaman wound the propeller 1,500 turns for a warmup flight and asked a judge to clock the test. His model set an unofficial world record for time aloft.

Confident that his rubber band motor could withstand 3,500 to 4,000 turns when wound with an egg beater, Kaman prepared to wipe out his new record. He began swiftly cranking the beater, but at about 3,000 turns the rubber band snapped, shattering the craft into a pile of sticks. Though discouraging, the incident only whetted his interest in aeronautic propulsion systems.

Hired after graduation in 1940 by the Hamilton Standard Division of United Aircraft in East Hartford, Connecticut, Kaman was assigned to work on propeller performance. He was later put in charge of aerodynamics for work that Hamil-

NASM

ton was doing for Sikorsky and his helicopter, the VS-300. In his work on the VS-300, Kaman became acquainted with its problems: lack of stability and control difficulty.

In his spare time he began to study the problems afflicting rotor blades, hoping to find a way to stabilize the rotor while making the helicopter easier to control. He started out affixing a hinged surface similar to an aileron—the movable surface on the trailing edge of an airplane wing—about three-quarters of the way out to the rotor blades' tips. Kaman figured these devices, attached by mechanical linkages to the pilot controls, would work as ailerons do in controlling the rolling movements of an airplane.

Scrounging around junkyards for parts and materials (a 1933 Pontiac, the rear end of an old Dodge truck, a bathroom scale, and a spruce plank all proved useful), Kaman built a test rig, which he kept in the garage of his mother's home in West Hartford. But rotor blades with the aileron-type attachment failed to give either lift or control. When the aileron flap was deployed downward, it provided momentary lift, but almost immediately the entire blade pitched nose-down, losing all lift. This happened, Kaman would soon discover, because the long and highly flexible blade wasn't rigid enough to contain the sudden lift gained by the lowering of the aileron flap. Instead the blade twisted downward each time and stayed that way until the aileron flap was raised.

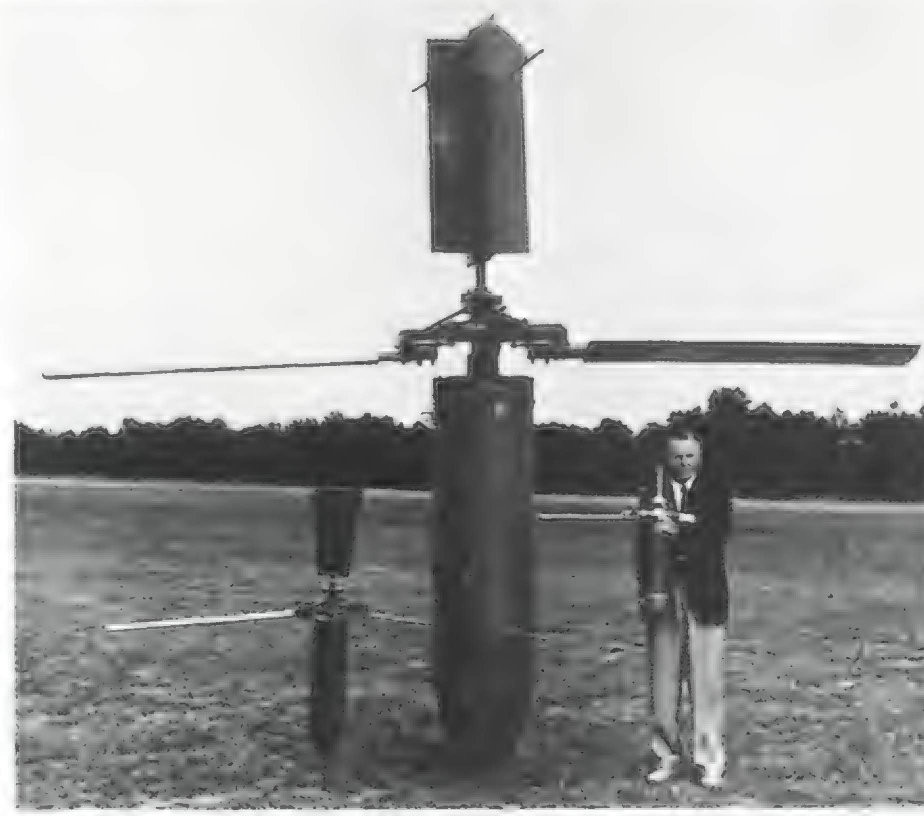
One Sunday morning, after several weeks of getting nowhere, he stood in the garage, his foot on the tire of the portable test rig, staring at the rotor. "It was then that it just plain hit me," Kaman, now 71, recalls. "I'd based the aileron idea on the fact that a rotor blade would be rigid, like a wing, which it wasn't." With this insight, Kaman stopped worrying about increasing lift and decided to take advantage of a blade's flexibility by finding a way to twist it. He decided to try a servo flap. Most helicopters of the day controlled blade pitch by using mechanical force at the rotor hub; servo flaps changed pitch by utilizing aerodynamic forces acting on the blade itself. Controlling pitch at the hub required a powerful mechanical force to move the entire blade. Since the surface area of the servo flap was much smaller than the blade, it took less force to move the flap and thereby control pitch.

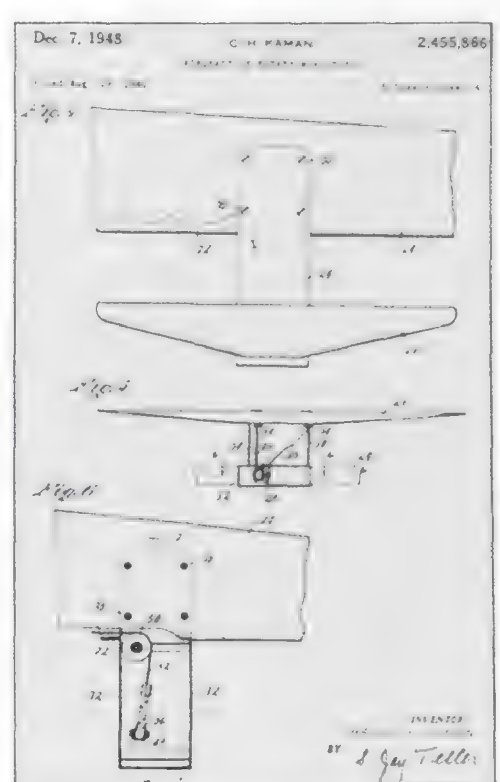
Unlike the aileron flap, the servo flap acted more like the elevator on an airplane's tail, changing the pitch of the entire blade. Although the two flaps were about the same size and looked much alike, Kaman bolted the servo to brackets, which extended from the front and back of the blade. The servo flap's separation from the blade was the key difference. After experimenting with different flap configurations, he settled on placing the device at the trailing edge of the blade, still at the three-quarters radius point.

The angle of the servo flap, controlled by the pilot, twisted the flexible blade into the desired pitch, eliminating the need to change pitch from the rotor hub. Moreover, by compensating for each blade's inconsistencies servos cut down on vibration.

Kaman tried to convince upper management of the servo flap's merits. When he successfully demonstrated his rotor blade test rig for Erle Martin, manager of engineering at United Aircraft, Martin told Kaman, "Charlie, we have our inventor at United Aircraft. His name is Igor Sikorsky. We don't need another one."

KAMAN CORPORATION (3)





Kaman was enthusiastic about his servo flap (left), but other helicopter manufacturers remained cool. Over the years Kaman's company also investigated remote-controlled aircraft (top) and developed "rotochutes," an alternative to the parachute designed to drop supplies from aircraft.

NASM

Sped to the scene by an H-43A, firefighters used the powerful downwash from the craft's dual rotors to beat back flames.

Kaman decided to leave the company. It was 1945, and the soon-to-be-established Kaman Aircraft Corporation now had the one inventor *it* would really need.

In planning his first helicopter, Kaman rejected the use of a tail rotor to counteract torque. Although he knew from the outset his design would need two counter-rotating rotors, he also dismissed the co-axial system, concerned that the two sets of blades, rotating one above the other, would collide. Kaman then reviewed the work of German aerodynamicist Anton Flettner, who prior to World War II had developed a helicopter with dual rotor heads and synchronized intermeshing blades. The German Navy had been enthused enough about Flettner's FL-282 to order 1,000 aircraft, but the end of the war halted the FL-282's development. Later the U.S. Navy became interested in such craft, which came to be known as "synchropters."

Kaman and at least one competitor, W. Wallace Kellett, decided to go with the synchropter. Still, other companies continued to use rotor hub systems to control blade pitch; only Kaman had servo flaps. The flaps gave his synchropters excellent stability, paving the way for Ann Griffin's flight.

Although the image of a helicopter for everyman was compelling, lack of public enthusiasm and post-war depression in the aviation industry spelled its doom. Nonetheless, the *Life* article on Griffin's flight perpetuated the proletarian helicopter myth. The piece suggested that once K-190s were mass-produced, enclosed-cockpit models would sell for $5,000.

Kaman already recognized that the future of rotary-wing craft depended on industrial, military, and agricultural applications. And yet, as an astute promoter and businessman, Kaman went along with the pleasant fiction, described by one newsreel narrator who intoned that "many observers feel helicopters have a future as air flivvers." The movie footage and *Life* story gave Kaman Aircraft a much-needed infusion of capital. As Kaman now says, "Every visitor to our Sunday demonstrations was a mark, a person to which we could sell stock." On the verge of insolvency, Kaman Aircraft could now fly on.

In the 1950s descendants of the K-190 and K-225 were purchased by the U.S. military and used for search and rescue missions. Still, no other helicopter companies successfully mass-produced synchroptic rotors, or even tried servo flaps. Russell H. Jones, a Kaman Corporation vice president, believes this was partially due to a "not invented here" attitude typical among manufacturers.

KAMAN CORPORATION

Although his company has diversified, Kaman remains fascinated by vertical flight.

Synchropters did have one distinct drawback: they were slow—dual rotors create more drag than a single-rotor system. "And after Korea, the military recognized a need for speed in helicopters," says Jones. When the helicopter industry converted from piston engines to gas turbines in the 1950s, helicopters gained more than enough muscle to power tail rotors. (A Kaman K-225 built for the Navy was the world's first gas turbine-powered helicopter. This aircraft now belongs to the National Air and Space Museum.) Although the company still believes in synchropters, one of its most successful helicopter lines, the Seasprite, uses a single main rotor/tail rotor design.

Kaman Aircraft manufactured helicopters until the mid-1960s, when Secretary of Defense Robert McNamara ordered the Seasprite out of production. But Kaman had already begun expanding his company's reach into aerospace parts manufacturing, aerodynamics subcontracting, and advanced nuclear research for the military.

Today, the Kaman Corporation, headquartered in Bloomfield, Connecticut—not far from the old gym at Bradley Field where Kaman's first helicopter was fabricated—has annual sales in excess of $800 million. Moreover, in 1981 the firm once again began producing helicopters, reopening the Seasprite production line to manufacture a modernized craft called the SH-2F, or LAMPS I (Light Airborne Multi-Purpose System), for the Navy. Employing servo flaps and a tail rotor, the SH-2F is a rugged submarine hunter and utilitarian aircraft for use on frigates and destroyers. The latest Seasprite model, the SH-2G, is finishing flight trials at the Navy's Patuxent River test center in Maryland and will be introduced into the fleet next year. And the company is seriously considering reopening a synchropter line, since there is a strong demand for its H-43 Huskies, an intermeshing helicopter known for its excellent safety record. Huskies are now being used for logging, petroleum exploration, and fire-fighting.

And yet for all Kaman's belief in diversification, it's clear that helicopters still have a grip on the designer. He is delighted by the U.S. Army's recent interest in servo flaps. Although progress has been made, even today's rotor blades produce vibrations that cause fatigue. "Servos can dampen them at the source," says Kaman. "Of course, we did a lot of this research 30 years ago, but today we've got microchips and the ability to put some intelligence and more precise control into the rotor heads, blades, and servos."

The research will likely improve on what Kaman discovered in the 1940s. But the flaps will be essentially the same ones that enabled Ann Griffin to prove that Charlie Kaman made birds that were wondrously easy to fly.

A Real Find

Shortly after the Challenger *blew up in January 1986, the Reagan administration formed a commission headed by William P. Rogers to investigate the disaster. Among the members was Richard P. Feynman, a Nobel laureate physicist who had worked on the atomic bomb. In a chapter entitled "The Cold Facts" from* "What Do *You* Care What Other People Think?", *his last book before his death in 1988, Feynman detailed a behind-the-scenes account of the commission's work and his participation in an important discovery. (General Kutyna is Donald J. Kutyna and Armstrong is Neil Armstrong, fellow commission members. Graham is William R. Graham, acting administrator of NASA, and Allan J. MacDonald and Lawrence B. Mulloy are key witnesses.)*

DOUGLAS EDWARDS (2)

That afternoon, I got a telephone call from General Kutyna.

"Professor Feynman?" he says. "I have some urgent news for you. Uh, just a minute."

I hear some military-type band music in the background.

The music stops, and General Kutyna says, "Excuse me Professor; I'm at an Air Force Band concert . . . ."

I could picture him in his uniform, standing at attention while the band is playing the "Star Spangled Banner," saluting with one hand and holding the telephone with the other. "What's the news, General?"

" . . . [W]e're going to have a special meeting tomorrow afternoon to hear from a guy whose story came out in the *New York Times* today . . . ."

Then he says, "I was working on my carburetor this morning, and I was thinking: the shuttle took off when the temperature was 28 or 29 degrees. The coldest temperature previous to that was 53 degrees. You're a professor; *what, sir, is the effect of cold on the O-rings?*"

"Oh!" I said. "It makes them stiff. Yes, of course!".

That's all he had to tell me. It was a clue for which I got a lot of credit later, but it was his observation. A professor of theoretical physics always has to be told what to look for. He just uses his knowledge to explain the observations of the experimenters!

On Monday morning General Kutyna and I went over to Graham's office and asked him if he had any information on the effects of temperature on the O-rings. He didn't have it on hand, but said he would get it to us as soon as possible.

Graham did, however, have some interesting photographs to show us. They showed a flame growing from the right-hand solid rocket booster a few seconds before the explosion. It was hard to tell exactly where the flame was coming out, but there was a model of the shuttle right there in the office. I put the model on the floor and walked around it until it looked exactly like the picture—in size, and in orientation.

I noticed that on each booster rocket there's a little hole—called the leak test port—where you can put pressure in to test the seals. It's *between* the two O-rings, so if it's not closed right and if the first O-ring fails, the gas would go out through the hole, and it would be a catastrophe. It was just about where the flame was. Of course, it was still a question whether the flame was coming out of the leak test port or a larger flame was coming out farther around, and we were seeing only the tip of it.

That afternoon we had our emergency closed meeting to hear from the guy whose story was in the *New York Times*. His name was Mr. Cook. He was in the budget department of NASA when he was asked to look into a possible seals problem and to estimate the costs needed to rectify it.

By talking to the engineers, he found out that the seals had been a big problem for a long time. So he reported that it would cost so-and-so much to fix it—a lot of money. From the point of view of the press and some of the commissioners, Mr. Cook's story sounded like a big exposé, as if NASA was hiding the seals problem from us.

I had to sit through this big, unnecessary excitement, wondering if every time there was an article in the newspaper, would we have to have a special meeting? We would never get anywhere that way!

But later, during that same meeting, some very interesting things happened. First, we saw some pictures which showed

puffs of smoke coming out of a field joint just after ignition, before the shuttle even got off the pad. The smoke was coming out of the same place—possibly the leak test port—where the flame appeared later. There wasn't much question, now. It was all fitting together.

Then something happened that was completely unexpected. An engineer from the Thiokol Company, a Mr. MacDonald, wanted to tell us something. He had come to our meeting on his own, uninvited. Mr. MacDonald reported that the Thiokol engineers had come to the conclusion that low temperatures had something to do with the seals problem, and they were very, very worried about it. On the night before the launch, during the flight readiness review, they told NASA the shuttle shouldn't fly if the temperature was below 53 degrees—the previous lowest temperature—and on that morning it was 29.

Mr. MacDonald said NASA was "appalled" by that statement. The man in charge of the meeting, a Mr. Mulloy, argued that the evidence was "incomplete"—some flights with erosion and blowby had occurred at ***higher*** than 53 degrees—so Thiokol should reconsider its opposition to flying.

Thiokol reversed itself but MacDonald refused to go along, saying, "If something goes wrong with this flight, I wouldn't want to stand up in front of a board of inquiry and say that I went ahead and told them to go ahead and fly this thing outside what it was qualified to."

That was so astonishing that Mr. Rogers had to ask, "Did I understand you correctly, that you said . . . ," and he repeated the story. And MacDonald says, "Yes, sir."

The whole commission was shocked, because this was the first time any of us had heard *this* story: not only was there a failure in the seals, but there may have been a failure in management, too.

Mr. Rogers decided that we should look carefully into Mr. MacDonald's story, and get more details before we made it public. But to keep the public informed we would have an open meeting the following day, Tuesday, in which Mr. Cook would testify.

. . . As we were leaving, Bill Graham came over with a stack of papers for me.

"Geez! That's fast!" I said. "I only asked you for the information this morning!" Graham was always very cooperative.

The paper on top says, "Professor Feynman of the Presidential Commission wants to know about the effects over time of temperature on the resiliency of the O-rings . . . "—it's a memorandum addressed to a subordinate.

Under that memo is another memo: "Professor Feynman of the Presidential Commission wants to know . . . "—from that subordinate to ***his*** subordinate, and so on down the line.

There's a paper with some numbers on it from the poor bastard at the bottom, and then there's a series of submission papers which explain that the answer is being sent up to the next level.

So here's this stack of papers, just like a sandwich, and in the middle is the answer—to the wrong question! The answer was:

"You squeeze the rubber for two hours at a certain temperature and pressure, and then see how long it takes to creep back"—over ***hours***. I wanted to know how fast the rubber responds in ***milliseconds*** during a launch. So the information was of no use.

I went back to my hotel. I'm feeling lousy and I'm eating dinner; I look at the table, and there's a glass of ice water. I say to myself, "Damn it, *I* can find out about that rubber ***without*** having NASA send notes back and forth: I just have to ***try*** it! All I have to do is get a sample of the rubber."

I think, "I could do this tomorrow while we're all sittin' around, listening to this Cook crap we heard today. We always get ice water in those meetings; that's something I could do to save time."

Then I think, "No, that would be gauche."

But then I think of Luis Alvarez, the physicist. He's a guy I admire for his gutsiness and sense of humor, and I think, "If Alvarez was on this commission, he would do it, and that's good enough for me . . . ."

I think, "Exactly! I've got to get a sample of the rubber." I call Bill Graham.

It's impossible to get: it's kept somewhere down at Kennedy. But then Graham remembers that the model of the field joint we're going to use in our meeting tomorrow has two samples of the rubber in it. He says, "We could meet in my office before the meeting and see if we can get the rubber out."

The next morning I get up early and go out in front of my hotel. It's eight in the morning and it's snowing. I find a taxi and say to the driver, "I'd like to go to a hardware store."

"A hardware store, sir?"

"Yeah, I gotta get some tools."

"Sir, there's no hardware stores around here; the Capitol is over there, the White House is over there—wait a minute: I think I remember passing one the other day."

He found the hardware store, and it turned out it didn't open till 8:30—it was about 8:15—so I waited outside, in my suitcoat and tie, a costume I had assumed since I came to Washington in order to move among the natives . . . . I hadn't bought an overcoat yet, so I was still rather conspicuous standing outside the hardware store in the snow.

At 8:30 I went in and bought a couple of screwdrivers, some pliers, and the smallest C-clamp I could find. Then I went to NASA.

On the way to Graham's office, I thought maybe the clamp was too big. I didn't have much time, so I ran down to the medical department of NASA . . . . I asked for a medical clamp like they put on tubes.

They didn't have any. But the guy says, "Well, let's see if your C-clamp fits inside a glass!" It fitted very easily.

I went up to Graham's office.

The rubber came out of the model easily with just a pair of pliers. So there I was with the rubber sample in my hand. Although I knew it would be more dramatic and honest to do the experiment for the first time in the public meeting, I did something that I'm a little bit ashamed of. I cheated. I couldn't resist. I tried it. So, following the example of having a closed meeting before an open meeting, I discovered it worked before I did it in the open meeting. Then I put the rubber back into the model so Graham could take it to the meeting.

I go to the meeting, all ready, with pliers in one pocket and a C-clamp in the other.

At the previous meeting, there was ice water for everybody. This time, there's no ice water. I get up and go over to somebody who looks like he's in charge, and I say, "I'd like a glass of ice water, please."

He says, "Certainly! Certainly!"

Five minutes later, the guards close the doors, the meeting starts, and I haven't got my ice water.

I gesture over to the guy I just talked to. He comes over and says, "Don't worry, it's coming!"

The meeting is going along, and now Mr. Mulloy begins to tell us about the seals. (Apparently, NASA wants to tell us about the seals before Mr. Cook does.) The model starts to go around, and each commissioner looks at it a little bit.

Meanwhile, no ice water!

Mr. Mulloy explains how the seals are supposed to work—in the usual NASA way: he uses funny words and acronyms, and it's hard for anybody else to understand.

In order to set things up while I'm waiting for the ice water, I start out: "During a launch, there are vibrations which cause the rocket joints to move a little bit—is that correct?"

"That is correct, sir."

"And inside the joints, these so-called O-rings are supposed to expand to make a seal—is that right?"

"Yes, sir. In static conditions they should be in direct contact with the tang and clevis and squeezed twenty-thousandths of an inch."

"Why don't we take the O-rings out?"

"Because then you would have hot gas expanding through the joint . . . ."

"Now, in order for the seal to work correctly, the O-rings must be made of rubber—not something like lead, which, when you squash it, it stays."

"Yes, sir."

"Now, if the O-ring weren't resilient for a second or two, would that be enough to be a very dangerous situation?"

"Yes, sir."

That led us right up to the question of cold temperature and the resilience of the rubber. I wanted to prove that Mr. Mulloy must have known that temperature had an effect, although—according to Mr. MacDonald—he claimed that the evidence was "incomplete." But still, no ice water! So I had to stop, and somebody else started asking questions.

The model comes around to General Kutyna, and then to me. The clamp and pliers come out of my pocket, I take the model apart, I've got the O-ring pieces in my hand, but I still haven't got any ice water! I turn around again and signal the guy I've been bothering about it, and he signals back, "Don't worry, you'll get it!"

Pretty soon I see a young woman, way down in front, bringing in a tray with glasses on it. She gives a glass of ice water to Mr. Rogers, she gives a glass of ice water to Armstrong, she works her way back and forth along the rows of the dais, giving ice water to everybody! The poor woman had gotten everything together—jug, glasses, ice, tray, the whole thing—so that everybody could have ice water.

So finally, when I get my ice water, I don't drink it! I squeeze the rubber in the C-clamp, and put them in the glass of ice water.

After a few minutes, I'm ready to show the results of my little experiment. I reach for the little button that activates my microphone.

General Kutyna, who's caught on to what I'm doing, quickly leans over to me and says, "Co-pilot to pilot: not now."

Pretty soon, I'm reaching for my microphone again.

"Not now!" He points in our briefing book—with all the charts and slides Mr. Mulloy is going through—and says, "When he comes to this slide, here, that's the right time to do it."

Finally Mr. Mulloy comes to the place, I press the button for my microphone, and I say, "I took this rubber from the model and put it in a clamp in ice water for a while."

I take the clamp out, hold it up in the air, and loosen it as I talk: "I discovered that when you undo the clamp, the rubber doesn't spring back. In other words, for more than a few seconds, there is no resilience in this particular material when it is at a temperature of 32 degrees. I believe that has some significance for our problem."

Before Mr. Mulloy could say anything, Mr. Rogers says, "That is a matter we will consider, of course, at length in the session that we will hold on the weather, and I think it is an important point which I'm sure Mr. Mulloy acknowledges and will comment on in a further session."

During the lunch break, reporters came up to me and asked questions like, "Were you talking about the O-ring, or the putty?" and "Would you explain to us what an O-ring is, exactly?" So I was rather depressed that I wasn't able to make my point. But that night, all the news shows caught on to the significance of the experiment, and the next day, the newspaper articles explained everything perfectly.

* * *

It was General Kutyna who called me up and said, "I was working on my carburetor, and I was thinking: What is the effect of cold on the O-rings?"

Well, it turns out that one of NASA's own astronauts told him there was information, somewhere in the works of NASA, that the O-rings had no resilience whatever at low temperatures—and NASA wasn't saying anything about it.

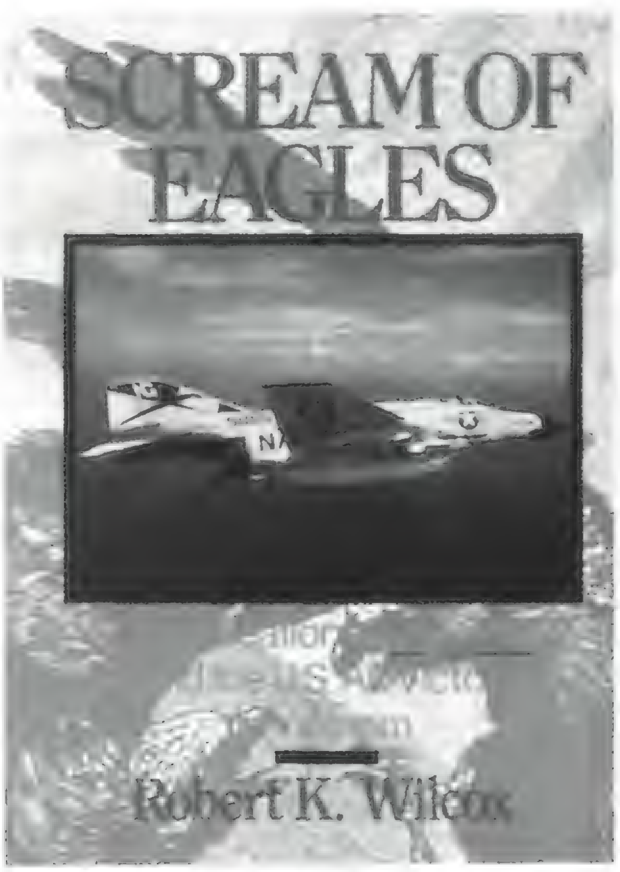
But General Kutyna had the career of that astronaut to worry about, so the *real* question the General was thinking about while he was working on his carburetor was, "How can I get this information out without jeopardizing my astronaut friend?" His solution was to get the professor excited about it, and his plan worked perfectly.

Reviews & Previews

Scream of Eagles: The Creation of Top Gun—And the U.S. Air Victory in Vietnam *by Robert K. Wilcox. John Wiley & Sons, 1990. 320 pp., b&w photos, $22.95.*

Scream of Eagles offers an inside look at the formation of the Naval Fighter Weapons School, the Navy's premier school for fighter pilots, recently associated more with Tom Cruise than with the war in Southeast Asia that spawned it.

Essentially an oral history, the book



draws largely on interviews with the pilots who pushed for and organized Top Gun in the late 1960s. The drawback to this approach is that the book is peppered with the usual braggadocio of fighter pilots. (One, recounting the one-on-one training missions at Top Gun, says he would "rather die than lose.") But it does provide an interesting glimpse into the mind of the silk scarf set, the stresses they faced in combat, and the professionalism they exhibited.

For nearly half the book author Robert Wilcox sets the stage for the school's formation with stories of individual dogfights over North Vietnam early in the war. By 1967 Pentagon planners had become anxious over the low "kill" ratios of these engagements. U.S. Navy and Air Force pilots were shooting down two MiGs for every one U.S. aircraft the North Vietnamese shot down. By contrast, the ratio registered by U.S. fighter pilots during World War II and Korea was roughly 10 to 1.

A key cause for the decline was the Navy's shift away from training in air combat maneuvering and its greater reliance on interceptor aircraft armed with long-range missiles to defend its aircraft carriers. The F-4 Phantom was designed without an internal gun, the fighter pilot's traditional weapon. Armed with the latest in radar tracking technology, the Navy brass thought Phantom pilots would no longer have to "mix it up" with other airplanes. Instead they could fire long-range missiles before the enemy even knew they were there. But over North Vietnam, hampered by strict rules of engagement, pilots found the concept impractical.

As *Scream of Eagles* progresses, a fascinating account unfolds of how a handful of dedicated Navy pilots on a shoestring budget, working secretly out of a small trailer at Miramar Naval Air Station in California, began pooling their expertise to create a training program to improve their performance in battle. They revived air combat tactics of the past and developed new ones, pushing themselves, their students, and their aircraft to the limits.

Initially, they ran into skepticism and the usual bureaucratic roadblocks. Top Gun instructors failed in their first attempts to obtain after-action reports of MiG engagements. The CIA finally let them read heavily guarded information on the MiG's capabilities—but would not let them take notes. Eventually the instructors were allowed access to a MiG-21 the Defense Intelligence Agency had acquired and began learning how to exploit the aircraft's weaknesses in secret training missions over the Nevada desert.

The concluding chapters are devoted to the successes scored by Navy pilots, most of them Top Gun graduates, in the latter stages of the war. By 1973, the Navy had increased its kill ratio to 12 to 1. Top Gun was responsible, and the lesson learned from that dramatic improvement in performance continues to be taught today.

—John Morrocco, senior military editor for Aviation Week & Space Technology, *is the author of two books on the air war in Vietnam.*

Cambridge Air and Space Dictionary *edited by Peter M.B. Walker. Cambridge University Press, 1990. 216 pp., $29.95 (hardbound); $12.95 (paperback).*

Aside from some presumably British peculiarities (the period-luminosity law is defined as "A relationship between the period and absolute magnitude, discovered by Miss Leavitt to hold for all Cepheid variables . . . "), this is a generally excellent desk reference. Especially noteworthy are its expanded entries, many illustrated, for such terms as "aerodynamics," "navigation systems," and "re-entry."

The SETI Factor: How the Search for Extraterrestrial Intelligence is Changing Our View of the Universe and Ourselves *by Frank White. Walker and Company, 1990. 250 pp., $18.95 (hardbound).*

SETI Pioneers: Scientists Talk About Their Search for Extraterrestrial Intelligence *by David W. Swift. University of Arizona Press, 1990. 434 pp., $35 (hardbound).*

The idea that intelligent beings exist on distant worlds is probably older than recorded thought, with roots in myth and religion. Even before the search for extraterrestrial intelligence (SETI) began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in earnest in 1959, when scientists started combing the heavens with radio telescopes for signals from other civilizations, numerous essays and books marked that ancient quest to find a mirror of ourselves in the heavens.

A difficult task, then, to find anything new on the subject. Yet two authors writing very different books, Frank White and *The SETI Factor* and David W. Swift and *SETI Pioneers,* have succeeded admirably in shedding new light on the topic.

Over the years, SETI has matured into a true science—actually a confluence of many sciences, including astrophysics, planetary astronomy, biochemistry, anthropology, radio astronomy, and others. Now NASA is gearing up for the most ambitious SETI effort ever, expected to start on Columbus Day 1992, when it will begin 10-year searches of the heavens. Though not well supported financially and not even much appreciated by outside scientists, SETI has managed to endure in its effort to answer one of the most humbling questions a sentient being could ask: "Are there others like me among the stars?"

The SETI Factor shares a philosophical niche with the author's book on the psychosocial dimensions of going into space, *The Overview Effect* (Houghton Mifflin, 1987). Frank White eloquently presents a host of contradictory and complementary opinions on extraterrestrial life, and on what encountering radio messages from other civilizations might mean for our own. "What is at stake . . . is nothing less than our understanding of what it means to be human," White proclaims. He also reminds us, however, that SETI is a search "for something that might not be there."

What kind of individuals dedicate themselves to such a search? In *SETI Pioneers* David Swift has satisfied a long-felt need by compiling his probing interviews with 17 SETI greats, including the very firsts: the well-spoken physicist Philip Morrison and his former colleague Giuseppe Cocconi, who helped launch the science with their seminal 1959 paper "Searching for Interstellar Communications" in the British journal *Nature,* and astronomer Frank Drake, who on cold nights in 1960 at the National Radio Astronomy Observatory in Green Bank, West Virginia, tinkered with his radio telescope's amplifier to conduct the first actual search. We also hear from Carl Sagan, Bernard Oliver, Charles Seeger (brother of Pete, the singer), Jill Tarter, John Billingham, Paul Horowitz, Freeman Dyson, Iosef Shklovskii, Nikolai Kardashev, John Kraus, and others less well known but no less pioneers.

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Through the support of the Guggenheim Foundation, the National Air and Space Museum sponsors a one year resident fellowship for scholars interested in historical and scientific research related to aviation and space.

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The Fellowship is open to predoctoral and postdoctoral applicants. Predoctoral applicants should have completed preliminary course work and examinations and be engaged in dissertation research. Postdoctoral applicants preferably should have received their Ph.D. within the past seven years.

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Eligibility:
The Fellowship is open to all interested candidates with demonstrated skills in research and writing. An advanced degree in history, engineering, or related fields is NOT a requirement.

Award:
12-month fellowship $26,000

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A. Verville Fellowship
National Air and Space Museum
Interpretive Programs, 3356B
6th & Independence Avenue, S.W.
Washington, D.C. 20560

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The interviewees were each asked the same set of questions, and their answers illuminate their roles in the evolving field as well as the personal factors that helped lead them there. Intriguing and delicious facts emerge: in several instances music played an influential role in turning these lives. Reaction to fundamentalist religions is another common theme. Passion for science runs throughout.

Those who are already SETI aficionados will find Swift's book a treasure of insights that humanize the field as never before. My only wish is that the interviews had been done more contemporaneously; they span more than a decade, requiring one to keep in mind that the answers apply to SETI in various incarnations. But that minor fault is offset by the wealth of wisdom gathered here, such as Carl Sagan's wonderment: "What has to be explained is not that some people are interested in [SETI], but that some people profess *not* to be interested in it. *That* is the amazing thing to me."

—Astronautical engineer Eugene F. Mallove is a science writer at MIT and the author of The Quickening Universe *and* The Starflight Handbook.

To Fly and Fight: Memoirs of a Triple Ace *by Clarence E. "Bud" Anderson with Joseph P. Hamelin. St. Martin's Press, 1990. 302 pp., $19.95 (hardbound).*

Bud Anderson is one of the leading aces of the Eighth Air Force's 357th Fighter Group, a P-51 Mustang team that during the World War II European theater was credited with shooting down 609½ enemy aircraft in only 15 months, a pace no other group equalled. The 357th also produced more aces than any other—42—one of whom was Anderson's buddy, Charles E. "Chuck" Yeager.

To Fly and Fight is a clear, straightforward narrative of what it was like to fly a Mustang on long bomber escorts and fighter sweeps, where the weather posed almost as great a threat as the enemy. The cold, miserable living conditions and the helpless feeling of watching a friend go down to capture or death were at least partly offset by the exhilaration of winning dogfights in the high bright sunlight above the clouds.

An aviation-struck California farm boy in the 1920s, Anderson pursued a career as an airplane mechanic before joining the U.S. Army Air Corps. The high-spirited antics of his squadron mates during fighter training in P-39s make up some of the book's many memorable moments. On one occasion the sheriff chased a few of the squadron's rowdy pilots out of a minuscule town in the Nevada desert. Bright and early the next morning one of the pilots revisited the town in his P-39 and shot its water tower full of holes.

Some people are natural pianists or artists; with a combination of skill, courage, and exceptional eyesight, Bud Anderson proved to be a natural fighter pilot. He was credited with shooting down 16¼ enemy aircraft in the course of two combat tours. Anderson's war adventures are not the climax of the book, however: his post-war experiences as a test pilot at Wright-Patterson and Edwards Air Force Bases are almost as hair-raising and certainly as interesting. He was involved in the testing of most of the first Air Force jets, from the P-80 to the F-104. He provides fascinating descriptions of the wild schemes to provide long-range escort capabilities to the fighters: one plan involved linking the aircraft together by their wingtips to save fuel; another envisioned F-84 Thunderjets being carried under the belly of B-36s.

The book closes on a high and somewhat poignant note in the late 1980s as Anderson and Yeager fly Mustangs painted to resemble Bud's "Old Crow" and Chuck's "Glamorous Glen III" in low formation passes at the annual Gathering of Eagles at Maxwell Air Force Base in Alabama.

All in all, *To Fly and Fight* is good reading for aviation buffs or for anyone who just enjoys a good story. I recommend it highly.

—Donald S. Lopez, senior advisor at the National Air and Space Museum, is the author of Into the Teeth of the Tiger.

Credits

"Midair!" Al White, a cockpit design and flight safety consultant, was a military and civilian test pilot from 1951 to 1966.

Out Where? Alex Heard is a Washington, D.C.-based writer who contributes frequently to Flights & Fancy.

Wing Man. David Noland contributed "Five for a Nickel" (Oldies & Oddities) to the June/July 1990 issue.

Amber Waves. Georg Gerster, who has published 17 books, is an internationally recognized aerial photographer.

Collision Insurance. George C. Larson is the editor of *Air & Space/Smithsonian.*

Mach 1: Assaulting the Barrier. Stephan Wilkinson, a former executive editor of *Flying* magazine, has just finished building an airplane that will fly considerably slower than Mach 1.

Further reading: *Supersonic Flight: Breaking the Sound Barrier and Beyond,* Richard Hallion, Macmillan, 1972.

Adventures in Research, Edwin P. Hartman, NASA, 1970.

Disaster at the Cosmodrome. James E. Oberg's last story for *Air & Space/Smithsonian* was "Inside Star City" (June/July 1990).

Flight School. Michael Parfit, a resident of Montana, is a frequent contributor to *Smithsonian* magazine. He wrote *Chasing the Glory: Travels Across America* (Macmillan, 1988) after touring solo across the United States by airplane and motorcycle, covering a total of 25,000 miles by journey's end.

Evidence of Cataclysm. George Greenstein's most recent book is *The Symbiotic Universe* (Morrow, 1988). He is a professor of astronomy at Amherst College in Massachusetts.

Grateful acknowledgment is made to the American Institute of Physics' Center for History of Physics for permission to quote from Richard F. Hirsh's interview with Herbert Friedman.

The Taming of the Copter. Jay Stuller is the co-author of *Through the Grapevine: The Business of Wine in America* (Wynwood Press, 1989).

Scooped in Space. Jay Mathews is the Los Angeles bureau chief for the *Washington Post.*

Statement of ownership, management, and circulation (required by 39 USC 3685) of *AIR & SPACE/Smithsonian*, published bimonthly at the Smithsonian Institution, 900 Jefferson Drive, Washington, DC 20560 for October 1, 1990 General business offices of the publisher are located at 900 Jefferson Drive, Washington, DC 20560. Name and address of publisher: Joseph J. Bonsignore, 900 Jefferson Drive, Washington, DC 20560. Name and address of editor: George C. Larson, 370 L'Enfant Promenade, SW, 10th Floor, Washington, DC 20024. Known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities: None. The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes have not changed during preceding 12 months (Section 411.3 DMM). The average number of copies of each issue during the preceding 12 months are: (A) Total number of copies printed: 367,224; (B) Paid circulation: (1) Sales through dealers and carriers, street vendors, and counter sales: 19,312; (2) Mail subscriptions: 321,797; (C) Total paid circulation: 341,109; (D) Free distribution by mail, carrier, or other means: 7,759; (E) Total distribution: 348,867; (F) Copies not distributed: (1) Office use, left-over, unaccounted for, spoiled after printing: 5,758; (2) Return from news agents: 12,599; (G) Total: 367,224. The actual number of copies of single issue published nearest to filing date are: (A) Total number of copies printed: 353,000; (B) Paid circulation: (1) Sales through dealers and carriers, street vendors, and counter sales: 19,466; (2) Mail subscriptions: 305,988; (C) Total paid circulation: 325,434; (D) Free distribution by mail, carrier, or other means: 9,352; (E) Total distribution: 334,786; (F) Copies not distributed: (1) Office use, left-over, unaccounted for, spoiled after printing: 4,748; (2) Return from news agents: 13,466; (G) Total: 353,000. I certify that the statements made by me are correct and complete

Carey O. Randall
Associate Publisher, Administration

Calendar

November 10–December 9
"Steichen and His Men: A Photographic Portrait of World War II." Smithsonian Traveling Exhibition. Fort Collins Museum, Fort Collins, CO, (303) 221-6738.

November 25–January 6
"Into the Sunlit Splendor: The Aviation Art of William S. Phillips." Smithsonian Traveling Exhibition. Dane G. Hansen Memorial Museum, Logan, KS, (913) 689-4848.

December 3–8
Avia India '90. India's first international exhibition and conference on civil aviation. Indira Gandhi International Airport, New Delhi, (202) 362-4764.

December 27–January 3
One-man show by space artist Andreas Nottebohm. Jill Vickers Gallery, Aspen, CO, (303) 925-5797.

January 5–February 17
"All Systems Go: America's Space Transportation System for the 1990s." Smithsonian Traveling Exhibition. Museum of Science and Industry, Tampa, FL, (813) 985-5531.

January 12–February 24
"Visions of Flight: A Retrospective from the NASA Art Collection." Smithsonian Traveling Exhibition. New Visions Gallery, Marshfield, WI, (715) 387-5562.

January 26–March 3
"The View From Space: American Astronaut Photography, 1962–1972." Smithsonian Traveling Exhibition. Denver Children's Museum, Denver, CO, (303) 433-7444.

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"The Satellite Sky" Update/21

These regular updates to "**The Satellite Sky**" chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

- Cosmos 2096 8-23-90 TT
- Cosmos 2101 10-1-90 TT
- Progress M-5 9-27-90 TT
- PRC-27 10-5-90 SHU

300 to 630 MILES

- Cosmos 2100 9-14-90 PL
- Fengyun 1-2 9-3-90 TAI
- Meteor 3-4 9-28-90 PL

630 to 1,250 MILES

- Cosmos 2098 8-28-90 PL

6,200 to 13,700 MILES

- GPS-9 10-1-90 CAC

21,750 to 22,370 MILES

- BS-3A 8-28-90 TAN
- Eutelsat 2 8-30-90 KOU
- Marco Polo 2 8-18-90 CAC
- Skynet 4C 8-30-90 KOU

Deletions

90 to 300 MILES

Cosmos 2089 down 10-1-90	KH-11 down (no date)	Resurs-F7 down 8-16-90

Inoperative but still in orbit

90 to 300 MILES	21,750 to 22,370 MILES
Delta Star	Cosmos 1888 GOES 6

Launched but not in orbit

90 to 300 MILES

Cosmos 2099 USSR photo recon	8-31-90	down 9-14-90
Progress M-4 USSR research	8-15-90	down 9-20-90
Resurs-F8 USSR earth sensors	8-16-90	down 9-1-90
Resurs-F9 USSR earth sensors	9-7-90	down 9-21-90
STS-41 US research	10-6-90	down 10-10-90

Forecast

In the Wings . . .

The Blimp Bowl. Football experienced as few have experienced it before: high above the stadium aboard a blimp.

Riveting. Riveters have an odd perspective on aviation: the way they see it, an airplane is nothing more than thousands of rivets flying in close formation.

Rocket Ranch. These amateur rocket scientists take their hobby seriously. From their clubhouse in the California desert, they prepare rockets that can soar up to 120,000 feet.

Exploring the Stratosphere. Once, it took intrepid balloonists to penetrate the secrets of the upper atmosphere. Getting there could be downright dangerous.

NASA Field Guide. The National Aeronautics and Space Administration isn't a single, localized entity. It has centers scattered around the country, and each has something unique that it can offer a space groupie.

Scooped in Space

Dear Mr. Akiyama:

Congratulations for being chosen as the first journalist in space. You have been entrusted with an almost sacred privilege. Your employer, the Tokyo Broadcasting System, also deserves to be congratulated for persuading the Soviet space agency Glavkosmos to take you, a Japanese reporter, to its Mir space station this December in exchange for $12 million.

American press reports out of Moscow say that your flight has outraged Soviet journalists. I will not pretend that word of your success was not also somewhat disheartening to me, Walter Cronkite, and 38 other U.S. journalists. Three years ago we thought we had this story within our grasp, but the U.S. Journalist in Space Project has faded into a bureaucratic mist.

After the tragic explosion of the *Challenger* and the death of its six astronauts and teacher Christa McAuliffe, the shuttle schedule was pushed far into the future. Some objected to including non-astronauts on shuttle missions. Eventually program officials were forced to put the journalist contestants on "temporary hold."

I was on a flight to Alaska when the *Challenger* exploded, so I avoided the uncushioned shock of seeing what had become a routine wonder turn to horror. When my wife told me about it on the telephone, I felt terrible—both for the families of the astronauts and for the blow I knew this would be to the one government program I thought would make a difference in the history of the species.

Yet the awful outcome of the *Challenger* mission made many of us only more eager to put a reporter in orbit. It seemed even more important for a journalist to explain in the clearest terms possible why the dangers had to be accepted so that we could discover where we fit in the scheme of the universe. With the future of the space program in jeopardy, it was suddenly imperative to send into space someone equipped to communicate that experience to the ordinary reader or viewer.

My boyhood dream was to be an astronomer, and it wasn't until I was in high school that I realized I would have to settle for amateur status. I started to read science fiction voraciously, especially anything by Joe Haldeman. (My favorite book of his is *Mindbridge.*) I joined the Planetary Society, and I usually voted for the candidate who promised to put up a space station or send a man to Mars (though I kept this to myself around my more socially conscious friends).

RICHARD THOMPSON

Realizing there was less chance of my being chosen for a trip in the shuttle than of a flying saucer landing in my wife's tomato garden (a favorite fantasy of mine), I decided to apply for the Journalist in Space Project. The 12-page application was similar to a college admission form: two short essays, two writing samples, three recommendations. I mailed the application with the kind of carefree feeling I have whenever I buy a lottery ticket.

Months later I learned that I had been selected from a total of 1,703 applicants as one of 100 regional semi-finalists. NASA and the Association of Schools of Journalism and Mass Communications, which ran the competition, said they wanted someone who could "communicate clearly and effectively in both electronic and print media." This seemed as likely as finding an all-American linebacker at MIT.

Somehow I stumbled through my audition in front of the camera. I also survived a grilling by a panel of journalists that included the drunken-astronaut test: If I discovered a member of my shuttle crew was an alcoholic, would I report it and risk alienating NASA? Without a doubt, I said. They seemed satisfied.

Still, I did not expect the telephone call the next morning informing me that I had made the final 40. I scanned the list of winners and sheepishly realized that several people who knew more about space and science had been eliminated. I had thought perhaps my best shot at becoming a semi-finalist was, as one letter of recommendation put it, that I was "fighter pilot size" (five-foot-six, 135 pounds) and would "fit in the machine." But I tried to put such thoughts aside by whispering to myself my argument to the panel: a non-expert might have a better chance of reaching the common man and woman.

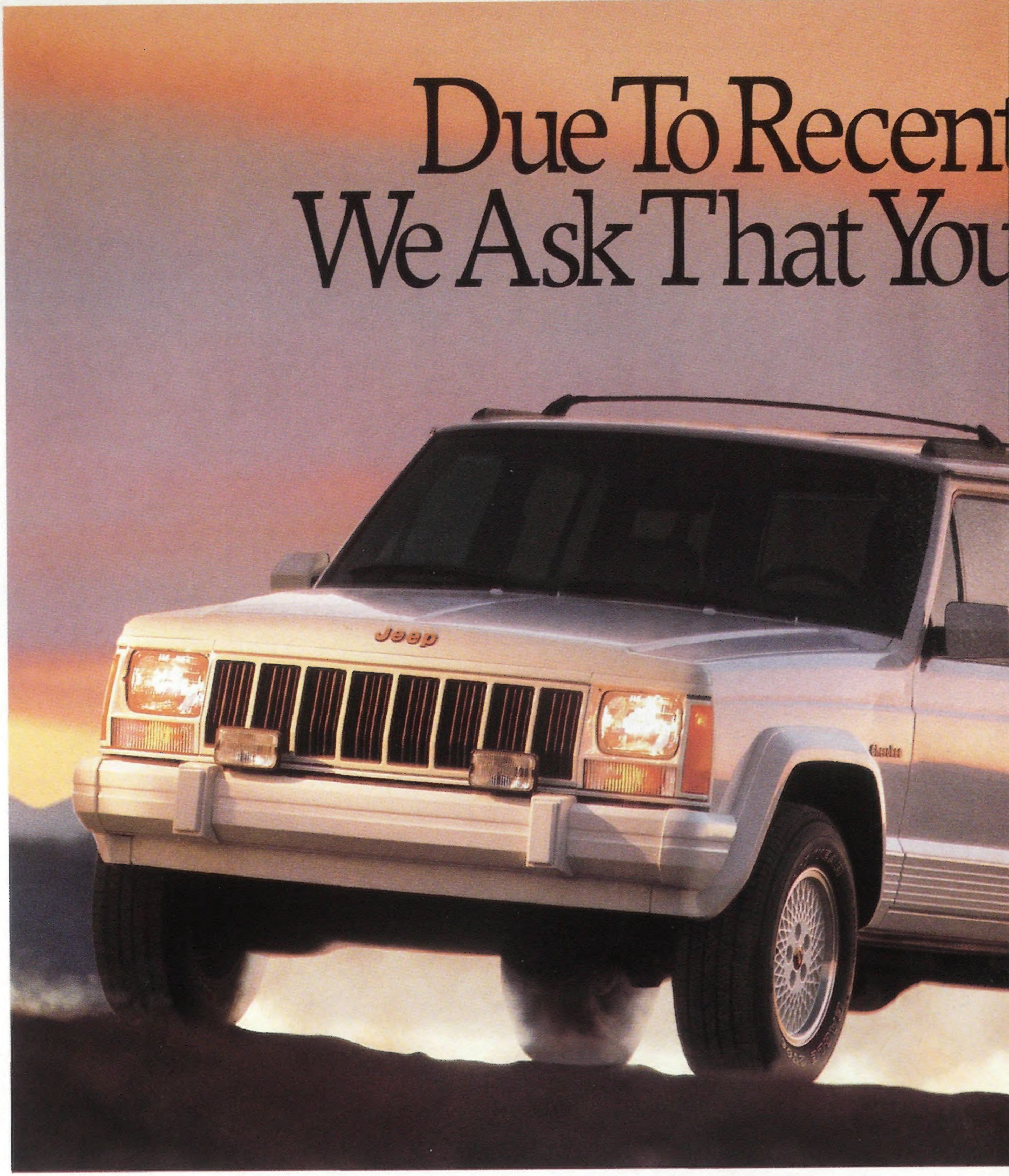
Making it to the semi-finals brought some fleeting moments of fame. My hometown newspaper, the *San Mateo Times,* printed a front-page picture of my father, mother, and brother displaying the spaceship wallpaper that had adorned my room as a boy. Shortly thereafter, however, I received the sad letter informing me that the rest of the contest had been indefinitely postponed and that my showdown with Walter Cronkite would probably never happen. A certificate was thoughtfully provided, which I had framed. But finding the memory painful, I ended up sticking it behind a file drawer.

I have since reconciled myself to the fact that my meager chance has passed me by. We will probably remain on hold past the day you tell your grandchildren about seeing the twinkling lights of Tokyo from 240 miles up. As you prepare to beat me and the rest of the world's journalists into orbit, I am ready to offer what I can to you. Perhaps when you have time, you could write and tell me how it goes.

Sincerely yours,

Jay Mathews

Jay Mathews



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